American Astronautical Society

American Institute of Aeronautics and Astronautics

2003 AAS/AIAA

Astrodynamics Specialist Conference

Big Sky Resort
Big Sky, Montana
August 3-7, 2003

PROGRAM

	General Chairs	Technical Chairs
AAS	Mark Soyka Naval Research Laboratory	Jean de Lafontaine Université de Sherbrooke
AIAA	Jon Sims Jet Propulsion Laboratory	Alfred Treder Dynacs Engineering Co. Inc.

This program is dedicated
to the memory of
Professor Vinod J. Modi
Professor Emeritus in Mechanical Engineering at the University of British Columbia
1929-2003

CONTENTS

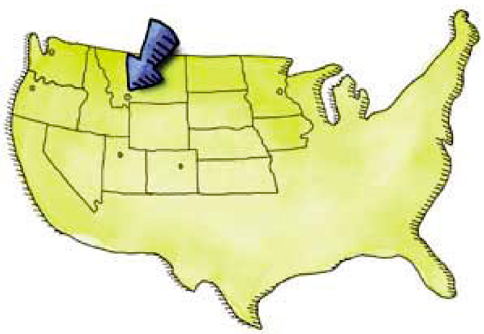
CONFERENCE LOCATION

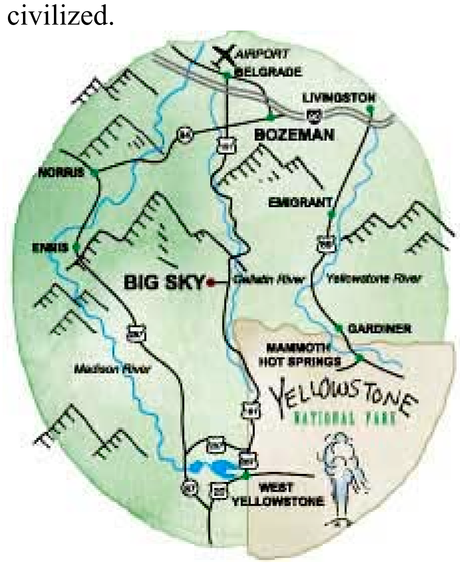
BIG SKY, MONTANA

The American Astronautical Society (AAS) and the American Institute of Aeronautics and Astronautics (AIAA) welcome you to experience the grandeur of the majestic mountains of Big Sky, Montana (U.S.A.) and the breathtaking views of Yellowstone National Park while sharing your latest research in Astrodynamics.

With Yellowstone and Grand Teton National Parks immediately to the south, untamed rivers in every adjacent valley, and no major population center within 350 miles, you can experience the romance of a young country, rugged and wild, from a setting that is unquestionably civilized.

Big Sky, Montana





The Resort offers beautiful accommodations at the Summit at Big Sky, a 213-room Euro-western luxury condominium hotel offering all the amenities required in a four-star setting. The Huntley Lodge and Shoshone Condominium Hotel offer the ultimate convenience with restaurants, lounges, shops, spas and the conference facility just steps from your room. Big Horn Condominiums and numerous other condominiums in a variety of sizes are within walking distance of the resort center.

Guests dine on excellent cuisine at numerous onsite restaurants and bars. Enjoy the heated swimming pool, tennis courts, and fitness center. Travel down the mountain and experience award winning fare at local restaurants. Peek out your window and see the local wildlife of deer and elk grazing in the fields, or stroll outside at dusk to witness a memorable star filled, crystal clear sky.

Located in Southwestern Montana, Big Sky Resort is situated at the base of Lone Mountain, rising high above the village. Wind your way up the scenic mountain road to the Resort. Explore the Gallatin River, teeming with wild trout and made famous by the film “A River Runs Through It” directed by Robert Redford and featuring Brad Pitt. Take exciting rafting trips on the river or horseback rides through meandering meadows and valleys. Hike up rugged trails (and not-so rugged trails) into untamed territory or ride a mountain bike. On the other hand, relax on the golf course or pamper yourself with a massage or other holistic treatments at the Spa.

Day Trips to West Yellowstone and Yellowstone National Park

Big Sky is located approximately one hour (less than 50 miles) from West Yellowstone and the northwest entrance to Yellowstone.

4X4 Stage: Departs daily at 7:45 a.m. from Big Sky. Reservations are required, minimum three people. Departs daily at 5 p.m. from West Yellowstone to return to Big Sky. Reservations are recommended at least 24 hours before departure. Please call (406) 388-6404 or (800) 517-8243, or stop by the Huntley Lodge Concierge Desk.

This transportation summary is compiled for your convenience. Information is correct at the time of printing but is subject to change. Please reconfirm travel plans before arrival.

Accommodations

Property Address:	Big Sky Resort P.O. Box 160001 #1 Lone Mountain Trail Big Sky, MT 59716-0001	Reservations: (406) 995-5000 Local (800) 548-4486 Out-of-State and Canada (406) 995-5001 Fax
Property Web Site:	www.bigskyresort.com	

Payment Terms: Major credit cards are accepted by the hotel.
Deposit policy: A deposit equal to one (1) nights lodging is required within ten (10) days of making the reservation, but no later than thirty days (30) before arrival.
Cancellation policy: Any rooms canceled within 30 days of arrival will forfeit the entire amount deposited. The property is a resort and, unlike hotels in big cities, cannot release and rebook rooms quickly.

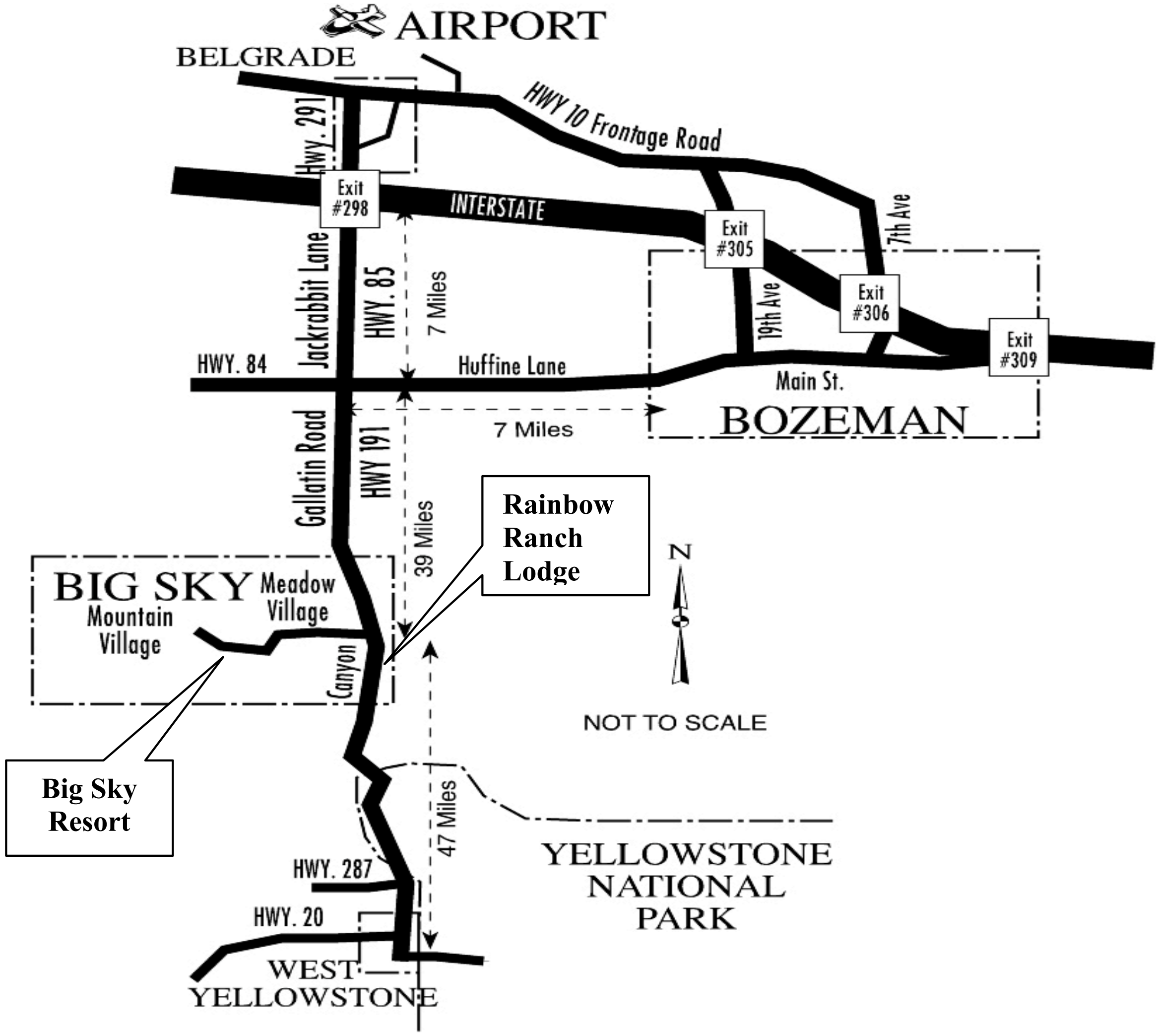
Check-in Time:	5:00 PM	Rooms are not guaranteed before this time
Check-out Time:	12:00 NOON	Huntley Lodge
	10:00 AM	Shoshone Condominium/Hotel & Summit at Big Sky
	10:00 AM	Condominiums

Access to Big Sky

The Gallatin Field Airport near Bozeman, located approximately one hour north of Big Sky, is the most convenient airport to the Resort. From Bozeman and the airport, Big Sky is a 45-mile drive through the scenic Gallatin Canyon. Both shuttles and rental cars are available at the airport. Taxi service from the Bozeman airport to the resort is available. Pre-arrangement with Karst Stage (www.karststage.com or by phone at 800-287-4759) at the airport is required. Rental cars are highly recommended so that you can make the most of your trip. Cars may be rented at Bozeman airport or in Big Sky. The Resort encourages exploration of the Meadow Village, Bozeman, West Yellowstone, Yellowstone National Park and other outstanding sites.

DIRECTIONS TO BIG SKY FROM THE GALLATIN FIELD AIRPORT: (See the maps)
Exit Gallatin Field by making a right hand turn onto Hwy. 10 (the frontage road). Drive 1.4 miles west through the small town of Belgrade. Turn left onto Hwy. 291. This road passes over Interstate 90 and becomes Hwy. 85 and then Hwy. 191. Proceed south 7 miles through the four-way stop on Hwy. 191. Continue south on Hwy. 191 for 32 miles. Turn right at the Big Sky Resort sign (yellow blinking light) and proceed 9 miles to the Mountain Village, passing through the Meadow Village. Turn left at the “Welcome to Big Sky Mountain Village” sign, then right at the next small intersection. Follow the road up to the seven-story complex, which is the Huntley Lodge/Shoshone Condominium Hotel and Yellowstone Conference

Center. The complex is 0.5 miles from the welcome sign. Drive safely, and enjoy the trip along the Gallatin River.



Another excellent option is to arrive in Billings, Montana. Located about 150 miles East of Bozeman, Billings presents itself as a somewhat arid, Western-like area with buttes. As you begin your two (2) hour drive towards Bozeman, you leave the Western countryside and enter rolling, lush green hills reminiscent of Ireland. Continue a little farther and the majestic Rocky Mountains suddenly appear towering above the foothills below. Climb into the mountains and you'll find yourself in Bozeman, a classic Western town with a 1930s feel to it. You'll then turn south on Rte 191 and follow the directions above.

Yet another option, is to fly into West Yellowstone airport, a small airport located to the south of Big Sky. For those adventuresome travelers, arriving at an airport in the Rockies (e.g., Salt Lake City) and a long, yet breathtakingly scenic drive to Big Sky would be worth the time.

DIRECTIONS TO THE RAINBOW RANCH LODGE FOR THE MONDAY NIGHT BARBEQUE:
From Big Sky Resort and the Mountain Village, proceed nine (9) miles down the mountain road to HWY 191, passing through the Meadow Village. Turn right (at the yellow blinking light) onto HWY 191, and continue five (5) miles south towards West Yellowstone. The Lodge is on the left side of the road, and there is a sign up at the entrance. There are two (2) parking lots for the guests, both of which are quite easy to find. Pull in either the dirt driveway right next to the horse stables (where only a small number of cars can be

parked) or in to the main lot which should accommodate everyone. The horse stables are on the northern edge of the property, and the paved lot is on the southern side of the main lodge.

AIR TRANSPORTATION: The Gallatin Field airport in Bozeman, Montana, has jet service daily on Delta, Northwest and Horizon. Skywest turbo-prop commuter aircraft also serve Bozeman. Delta and Skywest offer non-stop flights from Salt Lake City; Northwest offers non-stop flights from Minneapolis; and Horizon offers non-stop service from Seattle. Contact Big Sky Central Reservations at (800) 548-4486 for more information.

GROUND TRANSPORTATION: Big Sky Resort is located approximately one hour (less than 50 miles) from the airport. Several ground transportation options are available. All transportation conveniently delivers guests to the front door of the Huntley Lodge, Shoshone Condominiums and the Yellowstone Conference Center for check-in. Bellmen are available to assist guests with their luggage at the resort.

- **Shuttle Service**: The 4x4 Stage shuttle van has departures upon request. Tickets may be purchased from the transportation desk located near the baggage claim area inside the airport terminal. Reservations are recommended. Travelers also are advised to reconfirm their return to the airport at least 24 hours before departure. Please call (406) 388-6404 or (800) 517-8243.

- **Car Rental:** The following rental agencies are located in the airport or provide drop-off service for airport arrivals. There also are a limited number of automobiles for rent in Big Sky. Please call the Huntley Lodge Concierge Desk at (406) 995-5806 for more information.

Avis	(406) 388-6414	Hertz	(406) 388-6939	Thrifty	(406) 388-3484
Bozeman Ford	(406) 587-1221	National	(406) 388-6694	U-Save	(406) 587-9716
Budget	(406) 388-4091	Rent-A-Wreck	(406) 587-4551	Ugly Duckling	(406) 587-1000

AROUND THE RESORT:

- **Mountain Taxi:** Available by request. Please call (406) 995-4895 to request service.

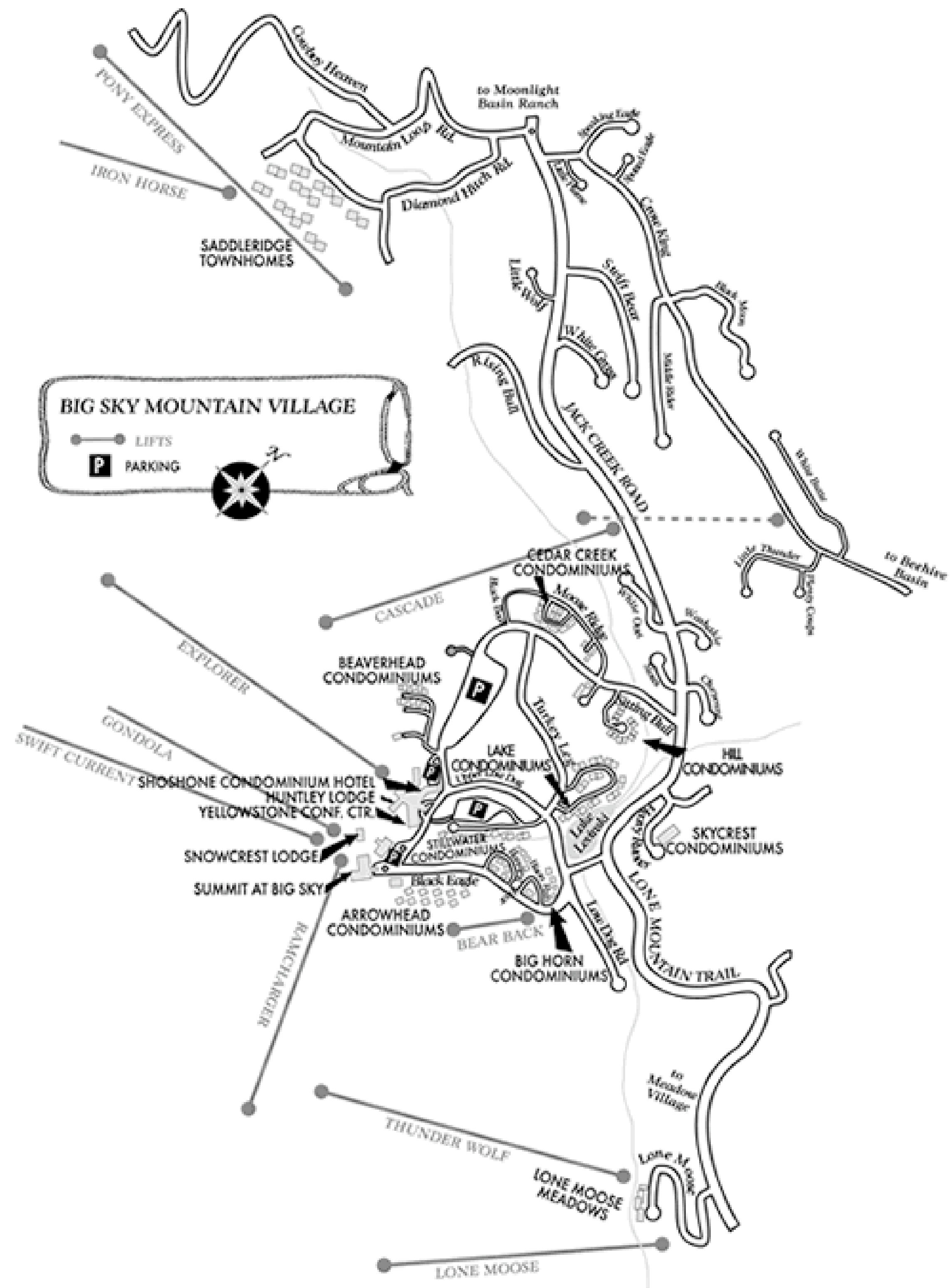
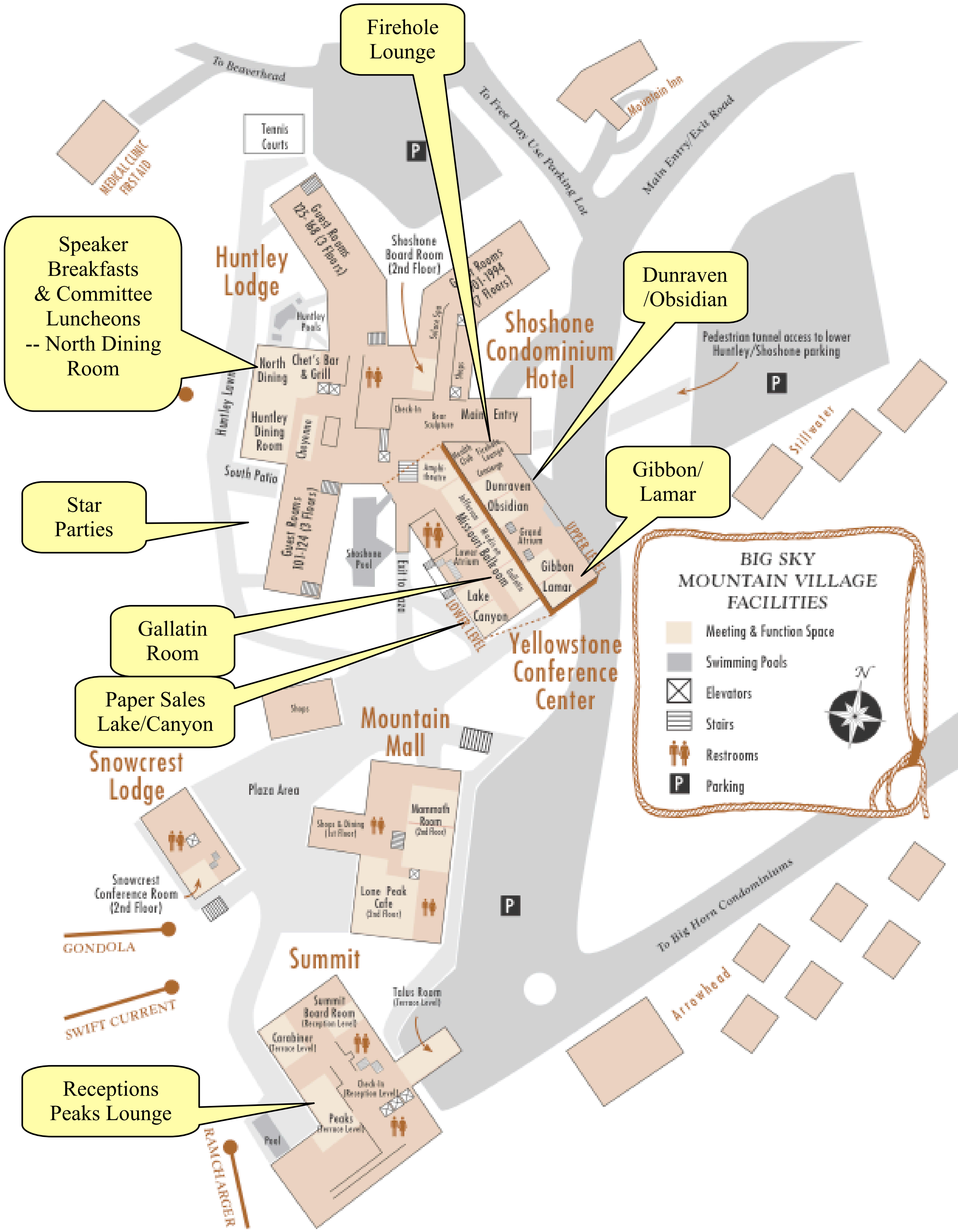


Figure 1 The Mountain Village at Big Sky


Firehole Lounge
Speaker Breakfasts & Committee Luncheons -- North Dining Room
Dunraven /Obsidian
Gibbon/ Lamar
Star Parties
Gallatin Room
Paper Sales Lake/Canyon
Receptions Peaks Lounge
To Beaverhead
Tennis Courts
To Free Day Use Parking Lot
Mountain Inn
Main Entry/Exit Road
MEDICAL CLINIC FIRST AID
Huntley Lodge
Guest Rooms 123-168 (3 floors)
Shoshone Board Room (2nd Floor)
Shoshone Condominium Hotel
Huntley Pools
North Dining
Chet's Bar & Grill
Huntley Dining Room
Cheyenne
Check-In
Bear Sculpture
Main Entry
Huntley Lawn
South Patio
Guest Rooms 101-124 (3 floors)
Shoshone Pool
Amphi-theatre
Dunraven
Obsidian
Grand Atrium
Gibbon
Lamar
Lake
Canyon
Missouri Ballroom
UPPER LEVEL
LOWER LEVEL
Yellowstone Conference Center
Pedestrian tunnel access to lower Huntley/Shoshone parking
Stillwater
BIG SKY MOUNTAIN VILLAGE FACILITIES
Meeting & Function Space
Swimming Pools
Elevators
Stairs
Restrooms
Parking
Shops
Mountain Mall
Snowcrest Lodge
Plaza Area
Mammoth Room (2nd Floor)
Lone Peak Cafe (2nd Floor)
Snowcrest Conference Room (2nd Floor)
GONDOLA
To Big Horn Condominiums
Summit
Talus Room (Terrace Level)
SWIFT CURRENT
Arrowhead
Summit Board Room (Reception Level)
Carabiner (Terrace Level)
Check-In (Reception Level)
Peaks (Terrace Level)
Pool
RAMCHARGER

MEETING INFORMATION

REGISTRATION

The following registration fees will be in effect for this conference:

- AAS or AIAA Members **$210.00**
- Non-members (Includes one year membership in the AAS) **$295.00**
- Students **$25.00**

Registration Schedule:

Sun Aug. 3	4:00 PM	--	08:00 PM
Mon Aug. 4	7:00 AM	--	04:00 PM
Tues Aug. 5	8:00 AM	--	04:00 PM
Wed Aug. 6	8:00 AM	--	04:00 PM
Thu Aug. 7	8:00 AM	--	10:00 AM

Registration and payment will be on-site only. No pre-registration is available. Checks should be made payable to the "**American Astronautical Society.**" At this time, payment by credit card is not accepted. Refer to the map of the hotel facilities for the location of the registration desk.

CONFERENCE PROCEEDINGS

The proceedings will be available to attendees of the conference at a reduced prepublication cost. Orders for the conference proceedings will be accepted at the registration desk. After the conference the proceedings will more than double in cost. Authors will receive a special 50% discount on the proceedings after the conference.

Cost of Proceedings

Conference Rate	$190
Post-Conference Rate	$450 (approximately)
Author Preferred Rate	$225 (approximately)

Special Events

Dr.Vinod J. Modi Photography Exhibit

Ms. Mira Modi

Ms. Modi brings an artistic venue of her late husband's photographical work that had been on display in Japan and India.

In addition to the Tuesday Modi Memorial Lecture, the display will be available for viewing at the Sunday Early-Bird Reception and at other locations Monday and Tuesday morning.

Sunday, August 3

Early Bird Reception

Peaks Lounge in the Summit, 6:00 – 9:00 P.M.

Star party

Michael Zedd, Naval Research Laboratory, David Vallado, Raytheon, Star Party Chairmen

Behind the Huntley Lodge, 9:00 – 11:00 P.M. (weather permitting)

Bring your jacket, as it will likely be cool.

Monday, August 4

Conference Welcome

Gallatin Room, 8:00 – 8:30 A.M.

Conference Overview, Mr. Mark T. Soyka, General Chair

State of the American Astronautical Society, Dr. Robert E. Lindberg, AAS President

Spouses, Partners, Family and Friends Tag-Up

Firehole Lounge, Huntley Lodge 9:30 A.M.

Meet for an Exchange of Ideas and Activities for the Week

Riverside barbecue at the beautiful Rainbow Ranch Lodge

6:30 – 11:00 P.M.

The special event for this conference will be at the Rainbow Ranch Lodge on Monday evening. A special outdoor riverside barbecue on the Gallatin River is scheduled with local entertainment. You're on your own for transportation. Driving directions from Big Sky Mountain Village are given in the previous ***Access to Big Sky*** *section. Tickets must be purchased at the registration desk in advance. Cost will be $30 for adults, $15 for children under 12 and free for kids under 3. Bring your coats, since this will be an outdoors event, or cozy up to the bonfire. We regret that the number of attendees at this special event is limited.*

Tuesday, August 5
2003 Vinod J. Modi Memorial Lecture
A plenary lecture in honor of Dr. Vinod Modi and his numerous contributions
to space flight and to the aerospace community
Gallatin Room, 5:30 – 6:30 P.M.

Dynamics and Control of Flexible Multibody Systems –
Contributions of Professor Vinod Modi
by
Professor Arun Misra

Star party
Michael Zedd, Naval Research Laboratory, David Vallado, Raytheon, Star Party Chairmen
Behind the Huntley Lodge, 9:00 – 11:00 P.M. (weather permitting)
Bring your jacket, as it will likely be cool.

Wednesday, August 6
Cocktail reception
Jefferson/Madison Rooms in the Conference Center, 6:00 – 8:00 P.M.

Rain Date – Star party
Michael Zedd, Naval Research Laboratory, David Vallado, Raytheon, Star Party Chairmen
Behind the Huntley Lodge, 9:00 – 11:00 P.M. (weather permitting)
Bring your jacket, as it will likely be cool.

Special thanks are extended to the Star Party Chairmen, Michael Zedd and David Vallado, both members of the AAS Space Flight Mechanics Technical Committee, for their hard work and dedication to making these extraordinary parties exciting and fun.

DINING OPTIONS AT BIG SKY

Chet's Bar & Restaurant: Located in the Huntley Lodge. Breakfast served from 6:30am to 10:30am, Bar open from 3:00pm to close. Food served from 4:00pm to 11:00pm. Nightly entertainment & live poker games

Carabiner and Restaurant: Located in the second floor lobby of the Summit. Breakfast served from 6:30am to 10:30am. Lunch served from 11:00am to 2:00pm, light menu served from 2:00pm to 6:00pm. Dinner served 6:00pm to 10:00pm. Room service is available from 6:30pm to 10:00pm.

Dante's Inferno: Located in the Mountain Mall. Lunch served Friday through Tuesday. Closed Wednesday and Thursday. Dinner served Saturday and Sunday. Ten (10) regional brews on tap, largest selection of single malt scotch, cognac & cigars in the area. Open daily 11 a.m. serving lunch & dinner, children's menu available, reservations recommended at dinner & large parties welcome.

MR Hummers: Located in the Mountain Mall. Lunch and Dinner served Monday through Friday. Closed Saturday and Sunday. Lunch & dinner, steaks, ribs & variety of sandwiches-lunch.

Black Bear Bar & Grill: Located east of the Huntley, past the large dirt parking lot. Open from 11:00am to 2:00am. Lunch served from 11:00am to 2:00pm. Dinner served from 5:00pm to 10:00pm. Call for information on nighttime entertainment 995-2845. Serving Mexican & American grill food. .Largest selection of microbrews in Big Sky; Open Mic Night Thurs & other weekly entertainment; pool tables; foos ball; darts; & poker machines (where the locals go!)

Sundog Café: Located in the Snowcrest building. Serving breakfast and Lunch including fresh baked pastries & bagels, espresso, sandwiches, wraps, soup, chili, baked potato bar, hot entrees & ice cream. Open 8 a.m.-5 p.m. daily.

C&P Grocery: Located in the Mountain Mall. Open daily from 10:00am to 6:00pm Selection of groceries, deli sandwiches and homemade soups, gift baskets, fresh produce, Montana gifts, beer & wine.

C & P Deli: located in C&P Grocery in Mountain Mall-serving breakfast & lunch to-go; great soups, sandwiches; wraps; daily specials. Extensive gourmet deli, great meat & cheese selection, fruit, veggie, meat & deli platters available to-go or for delivery. 995-4376

The Timbers: located at Moonlight Lodge; fine dining, spectacular views & warm atmosphere dine in casual comfort while enjoying our hearty sophisticated cuisine & grand fireplace. Fine dining, bar & deli open daily 995-7777

Meadow Village: 15 minutes drive from Mountain Village

Allgoods: (Bar & grill) Serving breakfast, lunch & dinner with large wine & beer list. Specializing in barbecue. 995-2750

Aromas: (Coffee shop) Featuring cappuccino, espresso beverages, & lunch. 995-4679

Blue Moon: (Bakery, Pizzeria, Café) Open 7 a.m.-10 p.m., locals favorite for fresh baked breads, pastries, pizza, sandwiches, soups, salads & specialty desserts. Non-smoking & family friendly. Located in Westfork meadow. Free delivery. 995-2305

By Word of Mouth: (Restaurant & bar) Delightful dining in casual atmosphere, from unusual to traditional, full bar, Wine Spectator "Award of Excellence" wine list, non-smoking. Serving lunch, dinner & Sunday brunch. Reservations recommended call 995-2992. Catering any occasion.

Cafe Edelweiss: Awesome food featuring veal, poultry, steaks, game & fresh seafood; nightly appetizer & entrée specials; children's menu; full liquor, imported beer & wine. Groups & private parties welcome; transportation available on SnowExpress; reservations recommended. 995-4665, www.cafeedelweiss.com

Country Market: Groceries, fresh meat & produce, full deli, beer, & wine. Open daily from 8a.m.-8p.m. Will deliver. 995-4636, 995-4633 (fax), e-mail: bigskycountrymarket@aol.com

First Place: (Restaurant & bar) Gourmet dining featuring seafood, steaks & game dishes; served 6-10 p.m. Reservations recommended. 995-4244

Huckleberry Café: Serving breakfast & lunch daily. Voted best breakfast in Big Sky. Located in the Grizzly Flats complex. 7:00 am –3:00pm 995-3130

Hungry Moose Market & Deli: Let us stock your kitchen before you arrive. Groceries, deli, produce, beer & wine. We have everything you need. Open 8 a.m.-9 p.m., we deliver. 995-3045, 800-277-9640, www.bigskygroceries.com

Lone Mountain Guest Ranch: (Restaurant & bar) Breakfast, lunch & dinner. Fine dining in elegant western atmosphere, a creative blend of world flavors & American regional cuisine. For reservations call 995-2782

Uncle Milkie's: Serving pizza, subs, calzones, & pita sandwiches & featuring a full bar. Open 4 p.m. for dinner. Family-casual atmosphere before 8 PM, adult-oriented later in the evening. Located in the Westfork Plaza. 995-2900

Gallatin Canyon: 20 minutes drive from Mountain Village

Big Horn Café: (Café & bar) Serving breakfast & lunch all day. Espresso & bar, dine in or takeout. Open Tu-Sun. 7:30a.m.-3:00pm. 995-3350

Buck's T-4: (Restaurant, bar, & grill) Open nightly; fine dining room featuring wild game specialties in warm, western atmosphere. Also featuring lounge, "Award Winning" Wine List, liquor store & grill offering sandwiches & pizza to stay or go. Free transportation available to and from restaurant. Reservations appreciated. 995-4111

Rainbow Ranch Lodge: (Restaurant & bar) Serving dinner in picturesque setting overlooking the Gallatin River. Northwestern cuisine & an extensive wine selection. Reservations suggested. 995-4132

Sliders Deli: Breakfast & lunch; serving sandwiches, soups, coffee, salads & hot dishes. Dine-in or take-out. Open from 7:30 a.m.-3 p.m. Located in Conoco gas station. 995-2566

The Corral: (Bar, café, steak house, motel) Breakfast from 7 a.m.-Noon, lunch served all day, & dinner from 5 pm-10 p.m. Featuring hearty steaks and sandwiches. 995-4249

320 Ranch: (Steak house & Saloon) Dinner in historic western steak house specializing in prime beef & wild game. Saloon opens at 4:30 p.m. with saloon menu & dinner served from 5 – 9 p.m. 995-4283

TECHNICAL PROGRAM

Technical Sessions

- This conference presents 170 professional papers on Astrodynamics and related topics in the equivalent of 21 full sessions (two of these are arranged as pairs of half-sessions), of which three are special sessions described more fully below. Three sessions will run in parallel each morning and afternoon of the conference, for three days plus Thursday morning.
- Morning sessions start at 8:30 AM and usually end by 11:40 AM. Lunch break is almost two hours. Afternoon sessions start at 1:30 PM and end by 5:00 PM (5:20 PM for Session 16 on Wednesday).
- The sessions break for 30 minutes of refreshments and conversation each morning at 9:50 AM and each afternoon at 2:50 PM.
- The professional sessions are held in three meeting rooms within the Yellowstone Conference Center building. The larger Gallatin Room is on the floor below the Dunraven/Obsidian Room and the Lamar/Gibbon Room. See the Big Sky Mountain Village Facilities map for location of the Conference Center and its meeting rooms relative to the other buildings.

Special Sessions

- The **Innovations in Aerospace Education** Special Session will be held Monday morning in the Dunraven/Obsidian Room.
- The **International Space Station** Special Session will be held Wednesday morning in the Gallatin Room.
- The **Neutral Density and Satellite Drag** Special Session will be held Wednesday afternoon in the Dunraven/Obsidian Room.

Presentations

- Each presentation is allocated 20 minutes total time, including questions and any preliminary setup. Session chairs will maintain this pace to assure that attendees can see presentations according to the posted schedule.
- Each room will be equipped with an overhead projector for transparent viewgraphs and also a projector that can be driven by a computer. However, the presenter has the responsibility for providing the necessary computer.
- The NO PAPER NO PODIUM rule will be enforced. The session chairs will verify the delivery of a reproducible plus 50 salable copies for every presentation in their sessions by the end of the applicable Speaker's Breakfast (see below). Lack of such timely delivery will constitute withdrawal of the paper.

Speakers' Briefings

Authors <u>who are making presentations</u> and session chairs of the day will meet for a short briefing at 7:00 AM on Monday and 7:30 AM on Tuesday, Wednesday, and Thursday, on the morning of their session. A breakfast will be served.

Location: North Dining Room of the Huntley Lodge

Paper Sales

Authors are required to bring 50 copies of their paper to the conference. The preprints will be on sale for $1.00 per paper in the preprint room adjacent to the meeting rooms. Bound copies of the conference proceedings may be ordered at the registration desk.

Location: Lake/Canyon Room

Volunteers

Volunteers are being sought to work at the registration desk and the paper sales room. If you wish to volunteer, contact one of the Conference Chairmen or sign-up at the registration desk.

Committee Meetings

Committee meetings will be held according to the following schedule:

AIAA Astrodynamics TC	Monday	11:30 AM - 1:30 PM
AAS Space Flight Mechanics TC	Tuesday	11:30 AM - 1:30 PM
AIAA Astrodynamics Standards	Wednesday	11:00 AM - 2:00 PM

Location: North Dining Room of the Huntley Lodge
Lunch will be provided.

PROGRAM SUMMARY

Date/Time		Event	Location
Sunday, 3 August			
	4:00 pm-6:00 pm	Conference Registration	Firehole Lounge
	6:00 pm-8:00 pm	Conference Registration	Peaks/Peaks Patio
	6:00 pm-9:00 pm	Early Bird Reception	Peaks/Peaks Patio
	6:00 pm-9:00 pm	Vinod Modi Photo Exhibit	Peaks/Peaks Patio
	6:30 pm- ?	Willie Nelson concert (tickets required)	Big Sky Meadow
	9:00 pm-11:00 pm	Star Party (weather permitting)	Behind the Huntley
Monday, 4 August			
	7:00 am-4:00 pm	Conference Registration	Firehole Lounge
	7:00 am-4:30 pm	Vinod Modi Photo Exhibit	Lake/Canyon Room (TBR)
	7:00 am-8:00 am	Speakers Breakfast	North Main Dining Room
	8:00 am-8:10 am	**Conference Welcome**, Mark T. Soyka	Gallatin Room
	8:10 am-8:25 am	**State of the AAS**, Robert E. Lindberg	Gallatin Room
	8:00 am-5:00 pm	Paper Sales	Lake/Canyon Room
	8:30 am-11:40 am	**Special Session** (Technical Session 1)	Dunraven/Obsidian Room
		Technical Session 2	Gallatin Room
		Technical Session 3	Lamar/Gibbon Room
	9:30 am	Spouses, etc. Tag-Up	Firehole Lounge
	11:30 am-1:30 pm	AIAATechnical Committee Luncheon	North Main Dining Room
	1:30 pm-5:00 pm	Technical Session 4	Dunraven/Obsidian Room
		Technical Session 5	Lamar/Gibbon Room
		Technical Session 6	Gallatin Room
	6:30 pm-11:00 pm	Riverside Barbecue	Rainbow Ranch Lodge
Tuesday, 5 August			
	7:30 am-8:30 am	Speaker Breakfast	North Main Dining Room
	8:00 am-4:00 pm	Conference Registration	Lake/Canyon Room
	8:00 am-4:30 pm	Vinod Modi Photo Exhibit	Lake/Canyon Room (TBR)
	8:00 am-5:00 pm	Paper Sales	Lake/Canyon Room
	8:30 am-11:40 am	Technical Session 7	Dunraven/Obsidian Room
		Technical Session 8	Gallatin Room
		Technical Session 9	Lamar/Gibbon Room
	11:30 am-1:30 pm	AAS Technical Committee Luncheon	North Main Dining Room
	1:30 pm-5:00 pm	Technical Session 10	Dunraven/Obsidian Room
		Technical Session 11	Lamar/Gibbon Room
		Technical Session 12	Gallatin Room
	5:30 pm-6:30 pm	**Modi Plenary Session** (A. Misra)	Gallatin Room
	9:00 pm-11:00 pm	Star Party (weather permitting)	Behind the Huntley (TBR)

Wednesday, 6 August

7:30 am-8:30 am	Speaker Breakfast	North Main Dining Room
8:00 am-4:00 pm	Conference Registration	Lake/Canyon Room
8:00 am-5:00 pm	Paper Sales	Lake/Canyon Room
8:30 am-11:40 am	**Special Session** (Technical Session 13)	Gallatin Room
	Technical Session 14	Dunraven/Obsidian Room
	Technical Session 15	Lamar/Gibbon Room
11:00am-2:00 pm	Standards Technical Committee Luncheon	North Main Dining Room
1:30 pm-5:20 pm	**Special Session** (Technical Session 16)	Dunraven/Obsidian Room
	Technical Session 17 & 18	Gallatin Room
	Technical Session 19	Lamar/Gibbon Room
6:00 pm-8:00pm	Happy Hour Cocktail Reception	Jefferson/Madison Room
9:00 pm-11:00 pm	Star Party Rain Date(weather permitting)	Behind the Huntley

Thursday, 7 August

7:30 am-8:30 am	Speaker Breakfast	North Main Dining Room
8:00 am-10:00 am	Conference Registration	Lake/Canyon Room
8:00 am-10:00 am	Paper Sales	Lake/Canyon Room
8:30 am-11:40 am	Technical Session 20	Gallatin Room
	Technical Session 21	Dunraven/Obsidian Room
	Technical Session 22 & 23	Lamar/Gibbon Room

CONFERENCE WELCOME

Welcoming Remarks for the
2003 AAS/AIAA Astrodynamics Specialist Conference

Monday, August 4, 8:00 – 8:15 A.M., Gallatin Room

Mr. Mark T. Soyka
AAS General Chair

Mr. Soyka will discuss the upcoming events of the week
and introduce the Chairmen and distinguished guests of the conference.

SPECIAL LECTURES / GUEST SPEAKERS

State of the American Astronautical Society

Monday, August 4, 8:15 – 8:30 A.M., Gallatin Room

Dr. Robert E. Lindberg
AAS President

Dr. Lindberg will provide a State of the Society address for the American Astronautical Society

---

2003 Vinod J. Modi Memorial Lecture

A plenary lecture in honor of Dr. Vinod Modi and his numerous contributions to space flight and to the aerospace community

Tuesday, August 5, 5:30 – 6:30 P.M., Gallatin Room

Professor Arun K. Misra

Dept of Mechanical Eng.
McGill University
817 Sherbrooke St. West
Montreal, QC, H3A 2K6
Canada

DYNAMICS AND CONTROL OF FLEXIBLE MULTIBODY SYSTEMS – CONTRIBUTIONS OF PROFESSOR VINOD MODI

Abstract

The first part of the seminar will present a description of selected works of Professor Vinod Modi on the dynamics and control of flexible multibody systems, in particular on dynamics of large space structures and platforms, dynamics and control of space manipulators and of tethered satellites. This description will be followed by the presentation of some recent work on multi-tethered satellite systems conducted by the speaker in collaboration with Professor Modi.

SESSION 1: INNOVATIONS IN ASTRONAUTICS EDUCATION
SPECIAL SESSION

Chair : Ron Lisowski
US Air Force Academy

08:30 AAS 03-500 Student Projects for Space Navigation and Guidance
L. Healy - University of Maryland

"Space Navigation and Guidance", ENAE 441, taught every fall at the University of Maryland, is required of all space track undergraduate majors. Every student is required to participate in a group project where real observations are used in the solution of an orbit determination problem. In this paper, I discuss two such projects, an observatory project in which the students use a telescope to track a satellite and determine its orbit, and a GPS project in which they analyze GPS receiver data to determine the receiver's position.

08:50 AAS 03-501 An Open-Source, Extensible Spacecraft Simulation Software Framework
A. Turner, C. Hall - Virginia Polytechnic Institute & State University

A spacecraft simulation framework was developed with the aim of providing researchers the ability to quickly test satellite algorithms while allowing them to view and extend the underlying code. The software is distributed under GPL (General Public License) and the package's extensibility allows users to add their own components to the libraries for investigating new algorithms, or tying in existing software or hardware components for algorithm and flight component testing. This paper presents the purpose behind the development of the framework, its underlying design architecture and implementation, and a roadmap for the future.

09:10 AAS 03-502 Visualization of Astrodynamics and Attitude Concepts for Education
A. Pederson, J. Woodburn, J. Carrico - Analytical Graphics

Three-dimensional visualization of position and attitude information for satellites and other vehicles is highly beneficial to learning the concepts and applications of astrodynamics and attitude determination and control. Being able to see and manipulate a three-dimensional view of complex numerical data such as orbit trajectories and attitude profiles gives students the ability to interact with the data in a physical, intuitive medium, rather than simply learning to ingest large volumes of raw numerical data. In addition to making the basic concepts of trajectories and attitude profiles easier to comprehend, visualization also clarifies the physical meaning behind the data associated with orbit determination (especially covariance analysis), orbital navigation, and Earth area and asset coverage.

Monday, 4 August AM

Session 1: Innovations in Astronautics Education **Dunraven/Obsidian Room**

09:30 AAS 03-503 Selecting Projects for a Capstone Spacecraft Design Course

D. B. Spencer, R. G. Melton, S. G. Chianese - The Pennsylvania State University

The first decision that goes into setting the tone for a senior capstone spacecraft design course is the choice of the projects. There are several sources of ideas for design projects, including design competitions and topics set by various technical committees. A new source of design ideas comes from "real world" design projects. The National Aeronautics and Space Administration (NASA) Office of Space Science (OSS) originally released an Announcement of Opportunity (AO) in the spring 2002 to solicit designs for a complete Mars mission. The Senior Capstone Spacecraft Design course in the Department of Aerospace Engineering at The Pennsylvania State University is paralleling this proposal process for their spacecraft design projects for the 2002-2003 academic year. While the original AO called for the individual groups proposing to determine what kind of a flight mission they will conduct, eight realistic flight missions were chosen and assigned to the eight teams in the class. Much of the important aspects of the original AO were duplicated; however, there was a significant amount of material that was deleted. This paper discusses the outcome of the yearlong course, compares some of the designs developed by the students to the designs chosen in the "real" NASA mission design, and comparing the outcome with approaches from previous years.

09:50 Break

10:20 AAS 03-504 Tele-Education in Aerospace and Mechatronics: the TEAM International Virtual Laboratory

J. de Lafontaine, C.-A. Brunet, G. Lachiver, J. Côté, D. Neveu, C.-E. Lemay, B. Biron - Université de Sherbrooke

The conduct of hands-on laboratory experiments is an important element in engineering education. It provides the students with the tools and the realistic environment to apply the theory learned in the classroom. In aerospace education, such labs are usually only provided in the areas of speciality of a given university and, due to limited budgets, other areas of theoretical interest are not covered by the laboratory. This abstract presents the TEAM project which aims at the sharing of laboratory equipment in aerospace control via the Internet. It also presents one of the Université de Sherbrooke's contributions to the TEAM project, the laboratory satellite TEAMSAT.

Session 1: Innovations in Astronautics Education **Dunraven/Obsidian Room**

10:40 AAS 03-505 When Spacecraft Won't Point

C. D. Hall - Virginia Polytechnic Institute and State University

In this paper, I describe Virginia Tech's undergraduate course in Spacecraft Attitude Dynamics and Control. One feature of the course is the extensive use of case studies to illustrate fundamental principles of ADCS implementations. Of particular interest are the ADCS failures that have occurred on actual spacecraft. The paper describes many of these failures, and includes references to failure reports, conference papers and other technical reports that describe these failures in more detail.

11:00 AAS 03-506 Satellite Attitude Dynamics & Control Demonstrations for the Classroom

R. G. Cobb, S. G. Tragesser - Air Force Institute of Technology

The spaceflight mechanics graduate courses are of core importance to the Air Force's Space Operations and Astronautical Engineering programs at AFIT. To enhance the students' comprehension of these topics, a combination of hardware demonstrations and graphical simulations have been woven into the curriculum. The hardware demonstrations are augmented with simulation movies using MATLAB. This paper describes the demonstration hardware and software routines, and explains how they are integrated into the current curriculum. The end result is that students are able to observe and interact directly with hardware leading to a more thorough understanding of the engineering principles of spaceflight mechanics.

11:20 AAS 03-507 Hardware-in-the-Loop Emulation of Satellite Flight Control Systems

D. L. Mackison - University of Colorado

Matlab, Simulink, Real Time Workshop and the dSpace 1104 Emulator Board allow the rapidly modeling of satellite attitude control systems. They can be modeled in software, and the dSpace emulator allows the Matlab/Simulink models to be directed connected to hardware test items- sensors, torquers, and computers. The computer with the Matlab model can directly command the flight hardware, and recover sensor data in hardware in the loop emulation. The system can be used to run complete command sequences to exercise all elements of the flight software, with the goal of avoiding untested loops, improperly scaled coefficient, or unanticipated interacting modes in the system operation in flight.

SESSION 2: MISSION & TRAJECTORY DESIGN-I

Chair : Jim McAdams
JHU Applied Physics Laboratory

08:30 AAS 03-508 A Geometric Analysis of Half and Full-Revolution Return Trajectories via Planetary Flybys
R. P. Russell, C. Ocampo - The University of Texas at Austin

For a spacecraft that performs a flyby of a planet with a specified hyperbolic energy, we systematically identify all trajectories following the flyby that will directly return after the planet makes n/2 revolutions of the primary, where n is any positive integer. The solution method is geometric and uses solutions from Lambert's problem when the terminal positions are parallel. The generalized direct return solutions may be used to construct loitering orbits about one celestial body or transfers between multiple bodies. Specific applications include cycler trajectories and planetary moon tours. Many previously documented cycler trajectories between Earth and Mars are improved using the discussed solutions.

08:50 AAS 03-509 Two-Synodic-Period Earth-Mars Cyclers with Intermediate Earth Encounter
J. M. Longuski, T. T. McConaghy - Purdue University

Spacecraft trajectories which repeatedly encounter both Earth and Mars may prove very useful in a future Earth-Mars transportation system. Such trajectories are known as Earth-Mars cyclers. We construct and analyze Earth-Mars cycler trajectories which repeat every two synodic periods and have one intermediate Earth encounter. Several new and notable cyclers are reported.

09:10 AAS 03-510 A Powered Earth-Mars Cycler with Three Synodic-Period Repeat Time
J. M. Longuski, K. J. Chen, T. T. McConaghy - Purdue University

We discuss a powered cycler for routine human transportation between Earth and Mars. The cycler is driven by low-thrust, high specific-impulse engines and repeats every three synodic periods. An attractive feature of this cycler is that inbound and outbound legs occur within the repeat time. Using this cycler, only three vehicles are required for a transfer opportunity to and from the Earth each synodic period. This cycler compares favorably with ballistic cyclers that require four (or more) vehicles, especially when considering the long-term cost to supply and maintain each vehicle.

09:30 AAS 03-511 **Mars Cycler Architectures Utilizing Low-Thrust Propulsion**
G. A. Rauwolf, A. L. Friedlander, M. Jacobs - Science Applications International Corporation; K. T. Nock - Global Aerospace Corporation

Mars Cycler orbits, originally explored in the 1960s, enable sustained human interplanetary transportation. Over the ensuing decades, several classes of cycler concepts, each with their own advantages, were developed. The Aldrin Cycler, in particular, enables many, relatively evenly spaced, short transits between Earth and Mars. However, the Aldrin orbits also require several modest deep-space delta-V maneuvers by their cycling spaceships to maintain on course. Those maneuvers were originally planned to be performed by chemical propulsion, but the high efficiency of maturing low-thrust propulsion systems make them attractive alternates for the chemical systems. This paper presents the results of applying low-thrust technology to the familiar concept of an Aldrin Cycler. In addition, it is applied to resupply vehicles required for the architecture presented here. Low-thrust technology successfully reduces the propellant required for the orbit corrections and ultimately the size of the vehicles involved without adversely affecting other aspects of the architecture. A comparison of the effectiveness of Solar-Electric Propulsion (SEP) and Nuclear-Electric Propulsion (NEP) will also be presented. This comparison demonstrates the payload regimes where SEP or NEP are preferred.

09:50 Break

10:20 AAS 03-512 **Trajectory Options for a Mars Sample Return Mission**
L. Casalino, G. Colasurdo – Politecnico di Torino

Withdrawn

The paper discusses several EP-trajecto[illegible] options to [illegible]rm the heliocentric legs of the Mars sample-return [illegible] ent strategies in terms of time-length and paylo[illegible] n particular, direct, Earth-Gravity-Assist (EGA[illegible] (EMGA) trajectories are considered for the out[illegible] Assist (MGA) trajectories are considered for the [illegible] ence of the hyperbolic excess velocity at Mars arrival (whose [illegible] is directly related to the braking strategy) is also discussed.

10:40 AAS 03-513 **A Comparative Assessment of Human Missions to Mars**
J. M. Longuski, D. Landau - Purdue University

There is no definite answer to how we shall go to Mars. In this paper, we develop a metric to assess the cost of Earth-Mars transportation systems, and consider how various propulsion choices, trajectory designs, and staging points affect these systems. Results are provided for both short-term (exploration) and long-term (settlement) scenarios. We find that in-situ resource utilization is most effective at reducing mission mass, and as vehicle mass increases, the propellant optimal system shifts from direct, to stop-over, to cycler scenarios – a tantalizing suggestion for the evolution of the human Mars transportation system.

11:00 AAS 03-514 Parking Orbits for Human Missions to Mars

J. M. Longuski, D. Landau - Purdue University

Several Mars mission scenarios incorporate a parking orbit at either Earth or Mars. In many cases the parking orbit is not conveniently oriented with respect to the desired hyperbolic velocity vector of the interplanetary leg (e.g., returning to Earth from a parking orbit at Mars). A method to reorient the spacecraft's orbit about a planet for a roundtrip mission is described. We also account for orbital precession effects during the parking orbit. We find that the reorientation cost can be kept below 500 m/s at Earth and below 250 m/s at Mars for many proposed missions.

SESSION 3: ORBIT CONTROL, ORBITAL TRANSFERS-I

Chair : Craig Kluever
University of Missouri-Columbia

08:30 AAS 03-515 Extension of Satellite Lifetime via Precision Pointing of Orbit Transfer Maneuvers

D. Javorsek II, J. M. Longuski - Purdue University

During any thrusting maneuver there is associated a velocity pointing error resulting in a component of the thrust in an undesired direction. Recent developments have yielded an alternate method to the common practice of spinning spacecraft at high spinrates to minimize these errors. The procedure of manipulating the thrust profile of a propulsion system to counteract these effects is called the Velocity Precision-pointing Enhancement System (VPES). By delaying the ignition transient of the thrust profile, large reductions in velocity pointing errors are realized. Here we discuss the mass savings from application of this method to current technology and draw conclusions regarding subsequent extensions of satellite lifetimes.

08:50 AAS 03-516 Effect of Thrust Profile on Velocity Pointing Errors of Spinning Spacecraft

D. Javorsek II, J. M. Longuski - Purdue University

Minute imperfections in spacecraft construction results in undesired off-axis body fixed torques which perturb the angular momentum vector in inertial space and result in velocity pointing errors of the vehicle. In this paper we expand on recent developments which provided analysis as well as a solution to this problem. Due to the coupled nature of the spacecraft attitude dynamics with the propulsion system, delaying the rise to maximum thrust results in substantial reduction of velocity pointing errors. Here we provide a detailed study of the results from using different thrust profiles to soften the ignition transient. We also discuss optimizing the trade-offs between the ignition transient delay time and delay thrust profile.

09:10 AAS 03-517 The Coupling, Longitude & One-year Propagation (CLOP) Strategy for Tight Eccentricity Control

J. F. Baker - New Skies Satellites N.V.

East/West Station Keeping (EWSK) strategies for Geostationary satellites implemented by Flight Dynamics Software systems in many Operations Control Centres around the world are definitely not optimal. This paper identifies and determines the underlying cause of inefficient EWSK manoeuvres and generates an optimal strategy (CLOP). Simulations of the CLOP strategy show the strategy to be more efficient than the old strategies in all cases and quantify the benefits to be gained. Along the way a software tool is developed to help plan optimal EWSK manoeuvres quickly and efficiently.

09:30 AAS 03-518 **Estimation of instantaneous maneuvers using a fixed interval smoother**
J. Woodburn, J. Carrico, J. R. Wright - Analytical Graphics

An alternative to the typical means of maneuver reconstruction and calibration is presented which uses the orbit determination algorithm directly to provide an estimate of short duration orbital maneuvers. The proposed method uses a sequential filter and fixed interval smoother to estimate the satellite state forward and backward across the time of the maneuver. The resulting maneuver estimate, which is derived directly from the normal orbit determination process, is supplemented by the existence of an associated covariance. Examples of this process using both real and simulated tracking data will be presented in conjunction with a comparison to standard reconstruction and calibration methods using least squares.

09:50 Break

10:20 AAS 03-519 **Third body driven vs. One impulse plane changes**
B.F. Villac, D.J. Scheeres - The University of Michigan

Third body driven plane changes, i.e. plane change maneuvers that uses 3rd body forces to reduce the costs of the maneuver, are compared to one impulse plane changes, the only classical approach still applicable in environments strongly perturbed by a third body. It is shown in particular that, while having inherent restrictions, the range of realizable 3rd body driven plane changes covers a wide range of initial conditions and is closely related to the existence of ±180° plane changes. The question of the optimal method for performing a given plane change with given initial conditions is addressed, both analytically and numerically, to help in the design of plane change maneuvers in 3rd body perturbed environments. In particular, contour plots of the optimal to perform all possible plane changes starting in a given circular orbit are obtained.

10:40 AAS 03-520 **Energy-Angular Momentum Plane Guidance Algorithm**
R. P. Patera - The Aerospace Corporation

A pitch steering guidance algorithm is presented that can be used for launch vehicle ascent and space vehicle orbit transfer involving high or low thrust applications. The method essentially parameterizes the orbit transfer trajectory in energy-angular momentum space, where only a low polynomial is required. Explicit dependence on time and vehicle acceleration is avoided in the parameterization. The method is well suited for trajectory optimization and provides optimized parameters for use in the vehicle guidance algorithm. The method was applied to launch vehicle ascent and orbit transfer cases. Results from simulation are provided.

11:00 AAS 03-521 A Guidance Strategy for the Radially Accelerated Trajectory

H. Yamakawa - Institute of Space and Astronautical Science (ISAS)

Orbital motion under a continuous outward radial acceleration as a function of the distance from the central body is analytically investigated. Two representative cases are analyzed in detail. One is the constant radial acceleration case, and the other assumes the radial acceleration inversely proportional to the square of the radial distance. Furthermore, a new guidance scheme for achieving the target maximum distance is established under radial acceleration disturbances. The proposed guidance scheme not only provides the control law of the radial acceleration, but also yields the required impulsive maneuver amount and timing to satisfy the guidance requirement at the terminal point.

11:20 AAS 03-522 Nonimpulsive Orbital Transfer Under Thrust Superposed and Correlated Deviations

A. D. C. Jesus, F. B. M. Santos - Universidade Estadual de Feira de Santana

In this paper we present the numerical analysis of nonimpulsive orbital transfers under thrust superposed and correlated deviations. We studied “theoretical” and “practical” (brazilian satellite EUTELSAT II-F2) transfers under influence of superposition and correlation of the gaussian, systematic (random-bias) and operational (white noise) deviations in the thrust vector. The “pitch” and “yaw” angles were taken like control variables, providing in each instant the minimum fuel consumption direction. Monte-Carlo analysis of the “theoretical” and “practical” orbits was realized, presenting results to one exact keplerian dynamic, which suggests one cause/effect relation between the semi-major axis of the orbits and the vector thrust direction deviations. This relation shows that the final orbit is so deformed w.r.t. the ideal cases (without deviations) and without deviations superposition or correlation. The deformation found in the final orbit shows too the loss of optimality of the system along the propulsive arcs. The cause-effect surfaces show the superposition (correlated or not) deviations effects over the propulsive arcs and all the results don’t depend of the: 1) kind of the errors distribution (uniform or gaussian); 2) transfer orbit (theoretical or practical); 3) kind of the errors (random-bias or white-noise).

SESSION 4: ORBIT DETERMINATION, NAVIGATION

Chair : Paul Cefola
MIT/Lincoln Lab

13:30 AAS 03-523 Geosynchronous Orbit Determination Using Space Surveillance Network Observations and Improved Radiative Force Modeling

R. Lyon, Z. J. Folcik, P. Cefola - MIT/ Lincoln Laboratory

This study is intended to improve orbit determination accuracy for 3-axis stabilized geosynchronous satellites via an improved radiative force model. The macro-model approach, developed earlier at NASA GSFC for the TDRSS spacecraft, has been adapted for the UNIX version of the Goddard Trajectory Determination System (GTDS) at the MIT Lincoln Laboratory. This paper describes software development and testing, including incorporation of a single-panel spacecraft model along with the full macro-model. The goal is to access these models from both the numerical and semi-analytical orbit generators within GTDS. This paper also describes a macro-model for the NASA Geosynchronous Operational Environmental Satellites (GOES) spacecraft, and presents the plan to tune this model and improve GOES orbits using observations from the Space Surveillance Network.

13:50 AAS 03-524 Comparison of accuracy for various size of geopotential model for Low-Earth-Orbit satellite Precision Orbit Determination using GPS observation

J. H. Jo, N. J. Choe, D. A. Cicci, J. E. Cochran, Jr. - Auburn University

In a previous study, the framework of a Low Budget Precision Orbit Determination (LBPOD) was completed. However, it did not utilize a full-scale geopotential model. In this paper, geopotential models with various sizes are examined to determine qualitatively the accuracies of each for low-Earth-orbit satellite precision orbit determination using GPS observations.

14:10 AAS 03-525 Sigma Point Kalman Filters for Efficient Orbit Estimation

D.-J. Lee, K. T. Alfriend - Texas A&M University

The standard Extended Kalman Filter is widely used for nonlinear estimation, its implementation, however, in orbit estimation under inaccurate initial conditions and sparse measurement data can lead to unstable solutions. In this article, efficient alternatives to the Extended Kalman filter are utilized for recursive nonlinear estimation of the states of an Earth-orbiting satellite. These are called as Sigma Point Kalman filters which include the Unscented Kalman Filter, and the Divided Difference Filter. The Unscented Kalman Filter is based on the nonlinear transformation called the unscented transformation, whereas the Divided Difference Filter adopts an alternative linearization method called a central difference approximation in which derivatives are replaced by functional evaluations. Simulation results indicate that the advantages of the filters make these attractive alternatives to the Extended Kalman Filter in the orbit determination.

14:30 AAS 03-526 Covariance Transformations For Numerical Operations

D. A. Vallado - Raytheon Intelligence and Information Systems

With the advent of numerical operations for many routine operations in space and the use of covariance information in particular, it's important to understand the different representations of the covariance matrix. Recent studies (Chan 2002, Peterson 2002, and others) have focused on the ever increasing role of covariance in determining probability for cllose-approach calculations. However, the format of these data is often given in a format that's not consistent with some of the modern applications. For instance, the US Strategic Command (USSTRATCOM) provides some covariance data from numerical operations in equinoctial elements, while the state vector is in Cartesian coordinates. To effectively process these data, transformations must be made between several formats. While most legacy programs contain FORTRAN code to accomplish this transformation, the exact partial derivatives are difficult, if not impossible to locate. This paper documents the transformations necessary to convert between Cartesian, Equinoctial, Flight, and Radial-transversenormal (RSW) coordinate systems. Detailed equations are given including assumptions, limitations (for small eccentricity and inclination values), and some sample test data. Both position and velocity vector components are included. For analysis problems, it's important to understand where the elements go to zero - specifically, is it along the eigenvectors? In addition, how important are the cross-terms in the transformations? Some transformations assume only the diagonal elements are needed for a particular transformation. Finally, discussion is given about the literature.

14:50 Break

15:20 AAS 03-527 Sensitivity of Mars Network Surface Navigation to Timing Errors

T. A. Ely, D. Bell - Jet Propulsion Laboratory

A key service of the Mars network will be to provide Doppler tracking measurements between a Mars surface asset and a Mars Network orbiter that can be used to determine the location of the surface asset. A requirement of the network is to provide tracking data of sufficient quality to enable position determination to better than 10 m (1-sigma) uncertainty. Numerous error sources impact the quality of this data, one of which is data time tag errors. This error manifests itself in the positioning process because the recorded time is used to query orbital trajectories and the location of the surface asset in inertial space. This paper documents analysis on the sensitivity of position determination to time tag errors and approaches for mitigating this error using estimation techniques and observation scheduling.

15:40 AAS 03-528 Satellite and Test Mass Dynamics State Estimation for Drag-Free Control

S. Theil, A. Schleicher – University of Bremen

Drag-Free Control is one of the enabling technologies for scientific space missions. Its application reduces the accelerations on a satellite to a low level which allows the execution of high sensitive experiments like on Gravity Probe B, STEP and LISA. One part of a Drag-Free Control system is the state estimation of satellite and test mass dynamics. A Kalman filter was designed by using the full dynamics model and reducing its complexity for utilization in the filter. The paper presents the dynamics model, the design of the state estimator and a comparison to an estimator using a different approach.

16:00 AAS 03-529 An Investigation of GPS Pseudolite Based Relative Navigation

E. Monda, G. Lightsey - University of Texas-Austin; K. Key, Titan Systems Corp

In this work, the use of GPS pseudolites is investigated at the Navigation Systems Testing Laboratory (NSTL) at NASA's Johnson Space Center in an attempt to achieve real-time indoor navigation. Based on work previously performed at the lab, an extended Kalman filter is used to process only carrier phase measurements. This work examines simulations of the system we expect to observe, and the resultant navigation capabilities we hope to achieve. Additionally, the results from processing data collected in the laboratory and additional challenges of the lab environment are presented.

16:20 AAS 03-530 Guidance and Navigation Strategy based only on the Range Measurement

J. Kawaguchi, H. Izutsu - The Institute of Space and Astronautical Science (ISAS)

The real-time navigation for the formation flight is discussed. The relative position and velocity are estimated, in case only the range data are provided and available. The navigation in those cases results in the 'active' navigation in which the observability is assured by applying the acceleration. The estimation process is governed by the non-holonomic system. The paper presents how the estimation process is guaranteed stabilized. What the paper proposes is a multi-step estimator to solve this non-linear simultaneous equation.

16:40 AAS 03-531 Orbit Determination Error Analysis Results for the Triana Sun-Earth L1 Libration Point Mission and for a Future Sun-Earth L2 Libration Point Mission

G. C. Marr - NASA Goddard Space Flight Center

Orbit determination error analysis results are presented for all phases of the Triana Sun-Earth L1 libration point mission and for the science data collection phase of a future Sun-Earth L2 libration point mission. These results can be applied to future Sun-Earth L1 and L2 libration point missions.

SESSION 5: TETHERS

Chair : Arun Misra
McGill University

13:30 AAS 03-532 Dynamics and Control of Tethered Satellite Systems for NASA's Specs Mission

M. Kim, C. D. Hall - Virginia Polytechnic Institute and State University

The control problems of two different configurations of Tethered Satellite Systems (TSS) for NASA's Submillimeter Probe of the Evolution of Cosmic Structure (SPECS) mission are studied and their control performances are compared. The configuration of main focus is the SPECS–Hex model comprised of three controlled spacecraft and three uncontrolled counterweights. This system is compared to a triangular TSS consisting of three controlled spacecraft. The equations of motion are derived using Lagrange's equations. Several mission scenarios for the SPECS mission considering the operation of an infrared telescope are introduced and asymptotic tracking laws based on feedback linearization are developed.

13:50 AAS 03-533 Detection and Identification of Two-body Tethered Satellite Systems

N. J. Choe, J. H. Jo, J. E. Cochran, Jr. - Auburn University

Most of previous studies focused on the detection and identification of tethered satellite systems utilized the observations from one satellite. In this study, we consider the problem of determining which pairs of many satellites for which we have observations are tethered. An algorithm is described that automatically determines which pairs are tether-connected in a region of sky. Since a single satellite experiences no tether force, discriminating tethered pairs from un-tethered pairs is performed by estimating the value of a supposed tether force per unit relative distance (Lagrange multiplier in this study) between all possible pairs of satellites. This process works very well under most circumstances. However, larger magnitude observation noise and short distance between two satellites may result in estimates of Lagrange multipliers that are non-zero numerically for two single satellites. Criteria for observation noise level and minimum relative distance between any two satellites is presented.

14:10 AAS 03-534 Dynamics of a Tethered Space Manipulator

M.-Y. P. Woo, A. Misra - McGill University

Dynamics of a rigid two-link robot manipulator connected to a spacecraft with a rigid, straight tether is considered. Torques can be applied at only two joints of this four-joint system. An analysis is conducted to obtain the workspace of the end-effector. A two-point boundary value problem is solved to determine the torques required to move the end-effector from one arbitrary attainable point to another.

14:30 AAS 03-535 Receding Horizon Control of Tether System Using Quasilinearisation and Chebyshev Pseudospectral Approximations

P. Williams, C. Blanksby, P. Trivailo - RMIT University;
H. A. Fujii - Tokyo Metropolitan Institute of Technology

This paper presents a new method for nonlinear receding horizon feedback control for general nonlinear systems. The proposed method utilises quasilinearisation to expand the system state equations to first order around reference trajectories. The calculus of variations is used to derive the necessary conditions for an optimal solution. The necessary conditions are discretised using a Chebyshev pseudospectral technique, which converts the differential equations into a set of linear algebraic equations that can be solved rapidly. The effectiveness of the proposed method is demonstrated by applying the technique in three example applications of the control of a space tether system.

14:50 Break

15:20 AAS 03-536 Artificial Gravity and Abort Scenarios via Tethers for Human Missions to Mars

J. M. Longuski - Purdue University ; M. D. Jokic - The University of Queensland;

Creating an artificial gravity environment and developing appropriate abort scenarios are important design goals for human missions to Mars. Our investigation reveals that a human transport can be designed so that it is capable of both sustaining an environment with artificial gravity and storing momentum to provide a propellant-free boost in the event of a mission abort scenario. A tethered transport offers clear benefits for human missions to Mars, and indeed, all human spaceflight.

15:40 AAS 03-537 Elastic Effects on Non-Planar Spin-Up End-body Dynamics of Artificial-Gravity-Generating Tethered Satellite System

A. P. Mazzoleni - Texas Christian University;
J. H. Hoffman - University of Texas at Dallas

This paper concerns analysis of the attitude dynamics of an artificial-gravity-generating tethered satellite system. Earlier work on this project was performed by treating the two sections of the satellite as point masses which were connected by a massless tether which was assumed to be inextensible and to remain straight throughout the deployment and retrieval process; the analyses to be presented in this paper will account for the elasticity of the tether, will treat the end-bodies as three-dimensional objects (as opposed to point masses) and will consider non-planar motion (an earlier study considered elastic effects but assumed that the motion was constrained to the orbital plane).

16:00 AAS 03-538 Dynamic stability of electrodynamic tethers in inclined elliptical orbits

J. Pelaez, Y. N. Andres - Universidad Politecnica de Madrid

This paper analyzes the effects of the side by side action of two forcing terms, the orbital eccentricity and the electrodynamic forces. The free parameters are: the eccentricity, the inclination and one electrodynamic parameter k. At first sight the eccentricity will reinforce the instability developed by the electrodynamic forces but this intuition has to be confirmed with a detailed analysis. Moreover, in some region of the parameter space, the electrodynamic instability becomes probably smother, because of the presence of the orbital eccentricity. The analysis will show the influence of the eccentricity on the eigenvalues of the monodromy matrix of the periodic solution. The values obtained for the circular orbit will be taken as reference to simplify the comparison between both cases, elliptical and circular.

16:20 AAS 03-539 Linear stability analysis of flexible electrodynamic tethers

L. Somenzi, L. Iess - Universita "La Sapienza";
J. Pelaez - Universidad Politecnica de Madrid

The purpose of this paper is to deepen the destabilizing mechanism which affects the electrodynamic tethers taking into account its flexibility. A linear analysis of the attitude dynamics of a flexible electrodynamic tether has been developed. The tether is considered insulated and the current constant. Besides the libration, the lateral oscillations are expanded in normal modes. Without current, the oscillations pertaining to orthogonal planes are uncoupled and, by averaging on time, the librations can be studied separately from the lateral modes because they have very different times scales. However, the current couples together all the oscillations which acquire frequencies of the same order.

SESSION 6: MISSION & TRAJECTORY DESIGN – II

Chair : Dennis Byrnes
Cal-Tech Jet Propulsion Laboratory

13:30 AAS 03-540 Solar Orbiter Trajectory Design
G. Janin - European Space Operations Centre

The ESA flexi-mission F2 Solar Orbiter project aims at exploring the uncharted innermost regions of our solar system. To this purpose, a heliocentric orbit of period 150 days with a perihelion of 40-50 solar radii is proposed. This orbit is reached through a ballistic cruise phase involving a series of Gravity Assist Manoeuvres (GAM) with Venus and Earth. As the duration of such a ballistic cruise phase is rather long (5 years), an alternative mission with a cruise phase of only 1.8 year is proposed, where the number of GAMs is reduced and five solar electric propulsion thrust arcs are inserted. As a continuation for both alternate missions, an extension is proposed where, through a 3.5-year series of 4 successive Venus GAMs on a resonant 3:2 orbit with the period of Venus, the inclination relative to the solar equator can be raised up to 38°. This allows a glimpse of the Sun's polar regions.

13:50 AAS 03-541 MESSENGER Mission Overview and Trajectory Design
J. V. McAdams - JHU Applied Physics Laboratory

MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) will be the first spacecraft to orbit the planet Mercury when this NASA Discovery Program mission begins its one-year Mercury orbit phase in 2009. The spacecraft will utilize two or three Venus flybys (two for the March 2004 baseline launch, three for the May 2004 backup launch) and two Mercury flybys during its 5-year ballistic trajectory to Mercury. The baseline and backup launch opportunities have similar designs for launch, planetary flybys, and propulsive maneuvers. The initial primary science orbit has 80° orbit inclination, 200-km periherm altitude, 60°N sub-spacecraft periherm latitude, and 12-hour orbit period.

14:10 AAS 03-542 Asteroid Deep Drill (ADD) Mission Plan
W. T. Fowler, M. M. Bailey, R. H. Bishop - University of Texas at Austin

The Earth has finite natural resources. Asteroids may prove to be a rich source of precious minerals and volatiles that could be mined for human use. Asteroid composition analysis can also provide a greater understanding of the evolution of the Solar System. This paper presents the design of an asteroid drilling mission to explore the mineralogical composition of the asteroid Vesta. The Asteroid Deep Drill (ADD) mission is designed to soft land an unmanned spacecraft on Vesta, drill into the asteroid, analyze regolith and subsurface samples, and communicate the data obtained back to Earth.

14:30 AAS 03-543 Effects of Gravity-assist timing on outer-planet missions using solar electric propulsion

B. Woo, J. W. Hartmann, V. L. Coverstone - University of Illinois at Urbana-Champaign; M. Cupples - Science Applications International Corporation

Outer planetary missions using a solar-electric propulsion system (SEPS) with a single Venus gravity assist are investigated. Delivered mass to the destination planet is maximized for a specified flight time. The trajectory characteristics of different Venus gravity assist timings are presented. The relation between the best performing set of trajectories and the distance of a target planet is determined. This relation can aid mission planners in selecting regions of the parameter space that offer superior performance among many local optimal solutions.

14:50 Break

15:20 AAS 03-544 A Preliminary Investigation of the Jupiter icy Moon Orbiter Trajectory

G. J. Whiffen - Jet Propulsion Laboratory

NASA's initiative to send a single electric propulsion spacecraft to orbit Callisto, Ganymede, and Europa within a decade will require a very complex trajectory. Strong multi-body effects combined with low-thrust control of capture and escape will make trajectory design very challenging. This paper describes an optimal trajectory that begins in low Earth orbit and ends in low Io orbit. A spacecraft following this trajectory will orbit Callisto, Ganymede, and Europa in succession before orbiting Io. This trajectory highlights the complexity, some of the risks, and also some of the advantages that can be exploited from using low-thrust in strong multi-body regimes. The optimization algorithm called Static/Dynamic Control was used to design the complete trajectory.

15:40 AAS 03-545 Control of Node Crossings in Saturnian Gravity-Assist Tours

N. Strange - Jet Propulsion Laboratory

In the Saturnian system, the control of the node-crossing point is important to avoid debris in Saturn’s ring plane and to target flybys of moons other than Titan. This paper describes how to use Titan gravity assists to control the spacecraft’s node crossings.

16:00 AAS 03-546 Cassini Tour Navigation Strategy

D. Roth, V. Alwar, J. Bordi, T. Goodson, Y. Hahn, R. Ionasescu, J. Jones
W. Owen, J. Pojman, I. Roundhill, S. Santos, N. Strange, S. Wagner, M. Wong –
Jet Propulsion Laboratory

Upon injection into orbit around Saturn in July 2004, Cassini will spend the next four years conducting investigations of Saturn and its satellites, rings, and magnetosphere. A strategy to navigate Cassini through 45 Titan flybys, seven icy satellite flybys, and a constantly changing orbital geometry has been developed. A brief overview of the trajectory is presented first, followed by a description of the maneuver strategy developed to maintain the nominal flyby aimpoints. Orbit determination of the spacecraft and nine Saturnian satellites is characterized next. Finally, as the satellite ephemeris is improved, the process and ΔV savings associated with updating the reference trajectory is discussed.

16:20 AAS 03-547 Simplifying Control of Interferometric Imaging Satellite Formations: Benefits of Novel Optical Architectures

L. Millard, D. Hyland - The University of Michigan

Limitations in existing formation flying optical system designs for long baseline, high resolution imaging of exosolar planets reduce feasibility, increase cost, and prolong the time before such systems could be deployed. In particular, numerous inter-spacecraft positioning and system geometry constraints must be satisfied to assure successful image formation. Our research attempts to reduce this system complexity through the use of different imaging system architectures. These architectures could relieve constraints on formation-keeping as well as vastly improve resolution of exosolar planets. One class of architectures is associated with *entry pupil processing* or more popularly*, digitized light*. In contrast *to focal plane detection* (standard interferometry wherein separate beams are propagated to a central location and then combined on a final photodetector), this concept refers to the approach whereby received radiation is converted to data (or downconverted to RF) at each of several light gathering devices (telescopes, mirrors, etc.) then the data is processed to synthesize the images. This approach can be implemented through a variety of direct electric field reconstruction or by means of multi-channel heterodyne detection. We focus attention in this paper on the latter technique.

SESSION 7: ORBITAL DEBRIS, COLLISION PROBABILITY

Chair : Jim Gearhart
Lockheed-Martin Technical Operations Co.

08:30 AAS 03-548 Relating Position Uncertainty to Conjunction Probability
S. Alfano - The Aerospace Corporation

This analysis shows the effects of positional uncertainty on the gaussian probability computation for orbit conjunction. Relative motion between two objects is assumed linear for a given encounter. A method is developed to map regions of maximum probability for various satellite sizes and encounter geometries. Those regions are then examined to assess probability dilution. The assertion is made that orbit positions should be sufficiently accurate to avoid these dilution regions. Charts are provided to assist the reader in determining orbital accuracy requirements that will prevent or minimize dilution of the probability calculations.

08:50 AAS 03-549 Spacecraft Collision Probability for Long-Term Encounters
K. Chan - The Aerospace Corporation

Most previous analyses have considered the two orbiting objects to move at high relative velocity toward each other so that they spend very little time in the encounter region. Thus, the relative velocity and the combined covariance error ellipsoid may be treated as constant. This is the case with low Earth-orbiting objects and many geosynchronous satellites. However, there are cases of encounters between satellites of the latter type for which the relative velocity is very low (meters per second or less) so that the time they spend in the encounter region is appreciable. During this period which can extend to well over a day, the relative velocity is no longer constant in direction nor can the combined covariance error ellipsoid be treated as constant. For encounters of this nature, a different approach to computing the collision probability must be used. The purpose of this paper is to formulate spacecraft collision probability for this more complex situation.

09:10 AAS 03-550 Describing Uncertainties on Orbit Parameters
D. Izzo - Università degli Studi di Roma "La Sapienza"

A number of important phenomena related to the space flight mechanics require considering a certain grade of uncertainty in order to be modelled satisfactorily. The lack of information on an object orbit may simply derive from the tracking error or the propagation error, but in many cases it can be of a more serious magnitude to the extent that many objects orbiting around our planet are on orbits on which very little can be inferred. A general approach to these kinds of problem is here proposed. The approach makes use of Dirac deltas to write a pdf associated to the position of an object along his orbit in deterministic conditions. The “dis-integration” technique, together with a theorem on the change of variable in generalized functions, is then used to introduce uncertainties on some orbital parameters. The results are some new analytical expressions that generalize previously known results such as Dennis theory and Öpik theory.

09:30 AAS 03-551 The Distribution of Closest Approach Distances Between Active Geostationary Satellites and Debris
C. Toews, E. Phelps - MIT/Lincoln Laboratory

MIT Lincoln Laboratory predicts and monitors encounters between active geosynchronous partner satellites and cataloged debris objects. Predictions are generated by propagating the position of a debris object forward in time and issuing a warning when the predicted distance of closest approach (DCA) to a partner satellite falls below some upper bound. Empirical histograms of the DCA from many encounters reveal a peak near 25 kilometers. This paper attempts to explain this peak by developing a statistical model of close approach distances based on orbital evolution in the near geostationary environment. Empirical results are compared both to an analytical model and to numerical simulations. Predictions are made about the evolution of the DCA histogram.

09:50 Break

10:20 AAS 03-552 Effect of Large Velocity Covariance on Collision Probability Computations
G. E. Peterson - The Aerospace Corporation

During collision probability computations, it is typically assumed that the velocity portion of the covariance can be ignored. However, when the relative velocity of the encounter is low, the velocity covariance could be significant in relation to the relative velocity. This study examines through Monte Carlo analysis the effect that such large velocity covariances have on the computation of the collision risk. An assessment of the typical sizes of the velocity covariance for on-orbit objects is performed and the likelihood that such low relative velocity / large velocity covariance encounters would occur is examined.

10:40 **AAS 03-553** **Separation Analysis for the STEREO Mission**

P. Sharer - JHU Applied Physics Laboratory Applied Physics Laboratory

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) is developing the Solar Terrestrial Relations Observatory (STEREO) spacecraft for launch in November 2005. The two spacecraft are stacked for launch aboard a 3-stage Delta rocket that will inject the spacecraft into a high-energy Earth orbit to facilitate a series of lunar gravity assists that ultimately place the spacecraft into heliocentric orbit. The deployment sequence from the launch vehicle features two separation events as well as the initial spacecraft attitude acquisition that may impart a significant residual velocity change. Geometric, analytic, and simulation-based analyses of the orbit dynamics associated with the separation sequence are presented.

11:00 **AAS 03-554** **Debris Mitigation Considerations for Geosynchronous Transfer Orbits With Supersynchronous Apogees**

A. Gick, C.-C. Chao, S. Campbell - The Aerospace Corporation

This paper summarizes a recent study of rocket bodies in geosynchronous transfer orbits with apogee altitudes above the geosynchronous belt. The purpose of the study is to determine guidelines for achieving reentry within 25 years. Reentry within 25 years is desirable due to the increasingly crowded LEO-to-GEO space zone. Both analytical and numerical investigations are performed to better understand the disposal orbit options and reentry sensitivities of the GTOs. The results suggest that a 25-year lifetime orbital decay guideline can be met by reducing perigee altitudes to about 200 km for the orbital parameters considered in this study. RAAN was found to have the largest effect on the variation of perigee altitude required for 25-year reentry. Further results demonstrate that lower inclinations produce smaller variations in perigee altitude.

11:20 **AAS 03-555** **The Catalogued Object Spatial Density for LEO; GEO and Molnyia Environments**

D. Izzo - Università degli Studi di Roma "La Sapienza"

The overcrowding of some particular zones of the space around the Earth is an accepted fact. Collisions between catalogued objects are now a concrete risk, a risk that has to be accounted for when designing any space mission. The construction of the catalogued object spatial density is an important step to assess many important quantities. A recent work extended the classically used Dennis equations to non constant probability density functions associated to the argument of perigee and to the RAAN. The new expressions are used in this work to study the catalogued population of LEO, GEO and Molnyia satellite at epoch September 2003. The new expression reveals a clustering of LEO satellites in the northern hemisphere, and makes it possible to study for the first time the object spatial density of the Molnyia satellites. Also the application to the GEO environment shows important features previously neglected.

SESSION 8: ATTITUDE DYNAMICS & CONTROL – I

Chair : Richard Longman
Columbia University

08:30 AAS 03-556 Magnetic Attitude Control for a Scientific Mission

F. Curti, L. Ascani, F. Longo - University of Rome "La Sapienza"

The scope of the present work is the development of an attitude control algorithm for AGILE, which is a low orbit satellite (altitude 550 Km), in the framework of Italian Space Agency small mission program, observing gamma ray sources. The nominal attitude is with the Z-axis pointing toward the sun and the Y-axis pointing at a target in the sky. Each observation campaign will last two weeks and during this phase the satellite must maintain, for each axis, the pointing accuracy within 1 degree and the pointing stability within 0.1 deg/sec. The attitude control is obtained by using a wheel mounted along the Z-axis and three coils along the principal axes of inertia. The wheel works in a double mode: as a momentum bias, to make the platform stable, and as a reaction wheel to make the platform controllable.

08:50 AAS 03-557 The High Accurate Attitude Determination And Control of Small Astronomical Satellite

H. Congying, G. Jian, Y. Zheng - Tsinghua Space Center, Tsinghua University;
Z. Jun - College of Astronautics, Northwestern Polytechnical University

This paper introduces a low-cost high-accuracy Attitude Determination and Control System (ADCS) of a small astronomical satellite. The ADCS's hardware and the idea of Instrument-in-Loop are presented. The emphasis of this paper is to design a high precision attitude controller based on the variable-structure control principle. The simulation result shows that this controller can effectively restrain the influences caused by uncertainty of models and low speed friction of reaction wheels, and implement large angle maneuver within approximate minimized time and under the restriction of reaction wheels' rate saturation. Furthermore, the ADCS configuration and control law are very easy to be realized onboard.

09:10 AAS 03-558 **Mixed Control Moment Gyro, Momentum Wheel, and Thruster Control Strategies**

C. E. Skelton II, C. D. Hall - Virginia Polytechnic Institute & State University

This paper develops control strategies that use single-gimbal control moment gyros for coarse large slew maneuvering and momentum wheels for precise control and error reduction due to initial conditions. Feedback linearization and Lyapunov control laws are developed from the governing equations. Numerical simulations of the derived mixed control moment gyro and momentum wheel control laws, as well as the thruster and momentum wheel control laws previously derived are evaluated. The control laws are implemented on the Distributed Spacecraft Attitude Control Simulator at Virginia Tech for evaluation and comparison.

09:30 AAS 03-559 **Definitions, Metrics, and Algorithms for Displacement, Jitter, and Stability**

M. E. Pittelkau – JHU Applied Physics Laboratory

This paper introduces pointing error definitions and metrics that are mathematically well-founded and are meaningful to imaging performance and to other types of instruments. These definitions and metrics are accuracy, displacement, jitter, stability, and windowed stability. These metrics are time-domain and frequency-domain formulas for computing variances. The frequency-domain formulas are particularly easy to apply. Useful metrics for displacement and jitter were introduced a decade ago but have not been utilized in requirements documents, and so they are reintroduced here. New definitions and metrics for stability and windowed stability are introduced in this paper.

09:50 Break

10:20 AAS 03-560 **Spillover Alleviation Technique for Flexible Space System Control Problem**

F. Curti, V. Coppi, M. Parisse - University of Rome “La Sapienza”

The paper presents an approach to reduce and/or suppress the spillover in the flexible spacecraft control problem. By using a new control technique, proposed in a previous paper (*Arduini C., Curti F, ” CORE – Constrained Optimal Regulator and Estimator”*, Automatica, 1995), it is possible to optimize the behavior of the system. The technique consists in imposing linear constrained on the elements of optimal regulator and estimator gain matrices, which is well suited to the Large Flexible Space Systems design.

10:40 AAS 03-561 Optical Payload Pointing and Vibration Isolation Using A Hexapod Platform

H.-J. Chen - Naval Postgraduate School; R. M. Bishop Jr. - National Reconnaissance Office; B. N. Agrawal - Naval Postgraduate School

For several future space missions, the pointing and vibration isolation performance requirements of optical payloads are becoming more stringent. At the Naval Postgraduate School, research is performed on achieving these stringent performances by using Precision Pointing Hexapod. Several controllers were developed and achieved ±0.008° accuracy for static pointing and accuracy of ±0.05° to ±0.2° for dynamic tracking of circles with various sizes and speeds. Vibration suppressions down to the noise floor in static pointing tests and at least 20dB reduction in the fundamental frequency in dynamic circle-tracking experiments were achieved simultaneously with pointing control.

11:00 AAS 03-562 Semi-Analytical Approach for the Integrated Structural/Control Optimization for a Space Station Model

P. M. Bainum - Howard University;
I. M. Fonseca - National Institute for Space Research

This study focuses on the integrated structural/control optimization applied to a space station model by using a semi-analytical approach. The procedure combines in one single formulation the optimization of the design of the structure and its attitude and vibration control. This challenging problem solution consumes much computational time and the cost may become prohibitive. In solving this problem, the greatest expenditure of time is associated with the numerical computation of the sensitivity derivatives, in general obtained numerically by finite differences. This work shows that the semi-analytical approach significantly reduces the CPU time involved in the numerical simulations.

SESSION 9: ORBITAL DYNAMICS

Chair : Felix Hoots
AT&T Government Solutions

08:30 AAS 03-563 A Simple Model for the Chaotic Motion around (433) Eros
A. Elipe - University of Zaragoza; M. Lara - Real Observatorio de la Armada

The three-dimensional motion in the close vicinity of Eros is known to be chaotic for a wide range of inclinations. This asteroid is potato-shaped, clearly distinct from an oblate body, and, therefore, classical perturbation theories for motion close to spheroidal bodies cannot be reliably applied.

The numerical approach to the problem through the computation of periodic orbits has been successfully applied in previous works, but even in that case one finds that the classical way of expanding the gravity potential in Legendre polynomial series may diverge at some points. Alternatively, polyhedra approximations can be used for modeling the motion in the close vicinity of the asteroid, but the evaluation of the derivatives of the potential for realistic models is highly time consuming. On the contrary, an extraordinarily simple dynamical model has been proposed for studying the motion around elongated bodies: the thin bar potential. With this theoretical model the gravitational potential may be expressed in closed form.

In this work we revisited the thin bar problem, and show that this simple,one-dimensional, model can give a qualitative explanation for the majority of the relevant dynamical features previously observed ---working with either general or special perturbation theories--- in the three-dimensional motion around Eros.

08:50 AAS 03-564 Spacecraft motion about binary asteroids
D.J. Scheeres, S. Augenstein - The University of Michigan

Spacecraft motion about asteroid binaries is a topic of interest for future missions to near-Earth asteroids. The binary environment integrates 4 classical problems of celestial mechanics into a single environment: the Hill problem, the restricted 3-body problem, the non-spherical orbiter problem, and the full 2-body problem. This paper focuses on the effect of the solar perturbation on the restricted 3-body problem, and shows that it leads to instability over a wide range of parameter space. We also provide a list of known asteroid binaries along with estimates of the stability of their environment.

09:10 AAS 03-565 Spheroidal Potentials and Gravitational Attraction from a Rod and a Disc

F.L. Janssens - Independent Consultant – Belgium

We show that the gravitational Newtonian potential of a disc and a rod on an external point are respectively prolate and oblate confocal spheroids. The potential of a disc is an approximation of a full oblate spheroid. In the equatorial plane spheroidal potentials are central and the energy integral is the trajectory in pedal coordinates. The velocity of circular orbits is hyperbolic close to the disc ($r < 1.08813$). The attraction of rods and discs could have large-scale applications. The potential of a point inside a ring is also given.

09:30 AAS 03-566 Finding periodic orbits with generating functions

V. Guibout, D.J. Scheeres - The University of Michigan

Periodic orbits are studied using generating functions. We develop necessary and sufficient conditions for existence of periodic orbits of a given period or going through a given point in space. These conditions reduce the search to either solving a set of implicit equations, which can often be done graphically, or finding the roots of an equation of one variable only, independent of the Hamiltonian system considered. We apply our results to periodic orbits in the vicinity of other periodic orbits and around the Libration points in the three-body problem.

09:50 Break

10:20 AAS 03-567 An Evaluation and Comparison of Relative Motion Theories

K. T. Alfriend, H. Yan - Texas A&M University

In this paper we will compare various theories for relative motion orbits. For example, we will take the projected circular relative motion orbit of radius □ and vary □ and compare the modeling error index. Two key parameters in the evaluation will be the eccentricity of the reference orbit and a size measure of the relative motion orbit, e.g., the projected circular orbit radius □.

10:40 AAS 03-568 Using Battin's Method to Obtain Multiple-Revolution Lambert's Solution

H. Shen - Analytical Mechanics Associates; P. Tsiotras - Georgia Institute of Tech.

In this paper, Battin's method for the Lambert's problem is extended to calculate the multiple revolution Lambert's solutions. It is shown that the original successive substitution method described in Battin's method converges to one of the two N-revolution solution with $N \geq 1$. If the order of the original successive substitution is reversed, then the reversed successive substitution converges to the other N-revolution solution. It is also shown that the original successive substitution converges to the N-revolution transfer orbit with the smaller semi-major axis, and the reversed process converges to the one with the larger semi-major axis.

11:00 AAS 03-569 Application of Local Lyapunov Exponents to Maneuver Design and Navigation in the Three-Body Problem

M. W. Lo, R. L. Anderson, G. Born - Jet Propulsion Laboratory

Dynamical systems theory has recently been employed for several missions to design trajectories within the three-body problem. This research applied a stability technique, the calculation of local Lyapunov exponents, to such trajectories. Local Lyapunov exponents give an indication of the effects that perturbations or maneuvers will have on trajectories over a specified time. Results from this technique present a possible explanation for the effectiveness of maneuvers at certain points on unstable orbits, and appear to have the potential to aid maneuver design. It also has applications to navigation and the planning of tracking for spacecraft missions.

11:20 AAS 03-570 An Analytical Solution to Kepler's Equation Using Chebyshev Approximation

L. Barker - Space Systems/Loral

Practical analytical expressions for the relationship between true anomaly and mean anomaly for the general orbit have been the pursuit of mathematicians for centuries. The transcendental nature of Kepler's equation prevents a pure analytical solution. Numerical techniques for determining true anomaly from mean anomaly are fast and accurate. However, they lack the beauty of being directly integratable. Iterative substitution methods of Kepler's equation, provide an analytical recursive expression, but results in a form that is neither differentiable nor integratable (i.e. sin(sin(sin(…))). It is possible to derive an orthogonal function from Chebyshev approximation and solve for the appropriate Chebyshev coefficients to express the true anomaly as a function of mean anomaly in polynomial form. It is also possible to fit the Chebyshev coefficients across the range of orbit eccentricity, thus arriving at an analytical expression that very accurately approximates the true anomaly as a function of mean anomaly and eccentricity. This form is differentiable and integratable, and comes with the powerful properties associated with Chebyshev functions such as truncation when less accuracy is required. In addition, when part of some higher function, the Chebyshev solution makes other analytical expression possible.

SESSION 10: OPTIMAL TRAJECTORY DESIGN & OPTIMAL CONTROL

Chair : Chris Hall
Virginia Polytechnic Institute and State University

13:30 AAS 03-571 **Optimal Round-Trip Interplanetary Trajectories Using an Advanced Pulsed Fusion Propulsion System**

S. Kahler, P. Lu - Iowa State University;
J. Hanson - NASA Marshall Space Flight Center

The calculus of variations is used to obtain optimum three-dimensional interplanetary transfer trajectories for a specified power-limited vehicle. The constant thrust program with coast capability used is governed by two-body orbital mechanics. The trajectory is broken up into departure and arrival spirals and a heliocentric transfer. A minimum heliocentric distance of .723 AU was maintained. The values of the parameters for the propulsion system modeled reflect those for Inertial Electrostatic Confinement (IEC) fusion and plasma linear driven Magnetized Target Fusion (MTF). Numerical results were obtained using VariTOP (Various Trajectory Optimization Program), which is a low to mid-thrust trajectory optimization and analysis program developed at the Jet Propulsion Laboratory.

13:50 AAS 03-572 **Optimization of High Power, Variable Specific Impulse, Roundtrip Interplanetary Trajectories from the Earth**

C. Ranieri, C. Ocampo - The University of Texas at Austin;
F. Chang-Diaz – NASA, Johnson Space Center

An indirect trajectory optimization method is used to compute high power (nuclear-electric), variable specific impulse, time-constrained optimal roundtrip trajectories from Earth to deep space interplanetary bodies. The thrust and/or specific impulse have lower and upper bounds and the engine efficiency is assumed to be a known function of the specific impulse. For human crewed missions, solutions are provided that maximize the stay time and minimize round trip time, while minimizing propellant. The results are applied to one year Earth-Mars roundtrip missions with a 2-month stay at Mars and four year Earth-Jupiter roundtrip missions with a one year stay at Jupiter.

14:10 AAS 03-574 Optimal Orbital Transfer Using a Legendre Pseudospectral Method

R. Proulx, S. Stanton, C. D'Souza - The Charles Stark Draper Laboratory

Orbital transfer problems are solved successfully for several classes of transfers, including coplanar transfer, simple plane change, and complex orbital size/shape/plane changes. Both impulsive and finite-burn orbital transfers are constructed which minimize fuel costs. Using DIDO, the direct Legendre pseudospectral technique software package developed by Ross and Fahroo of the Naval Postgraduate School, the effects of complex perturbations, (like J2 and atmospheric drag) are naturally included in the optimal solution. Written in Matlab, the DIDO package allows the user to incorporate complex cost functions, bounds, and constraints on the optimal transfer trajectory through a standardized interface.

14:30 AAS 03-575 Solving optimal control problems with generating functions

D.J. Scheeres, V. Guibout, C. Park - The University of Michigan

We study the fuel optimal control of a spacecraft as it transitions between specified states in a fixed amount of time. We approach the solution to our optimal control problem with a novel technique, treating the resulting system for the state and adjoints as a Hamiltonian system. We show that the optimal control for this system can be found once the F1 generating function for the Hamiltonian system is found. We also pose a solution procedure for this generating function and apply it to this particular case.

14:50 Break

15:20 AAS 03-576 Combined Long Duration Finite Burns and Gravity Assist Interplanetary Trajectories using an Indirect Method with Analytical Gradients

S. Zimmer, C. Ocampo - The University of Texas at Austin

A procedure for calculating the analytical derivatives required for an indirect optimization method of combined, long duration finite burn and multiple gravity assist trajectories is presented. The analytical derivatives are calculated using the state transition matrix associated with the complete set of the Euler-Lagrange equations of the optimal control problem on each trajectory segment as well as a state transition matrix that maps perturbations across any discontinuities in the state due to a flyby or impulsive maneuver. As an application, the method is used to find Earth to Saturn trajectories that use combined low thrust and gravity assists.

15:40 AAS 03-577 Computation of Optimal Mars Trajectories via Combined Chemical/Electrical Propulsion, Part 3: Compromise Solutions

A. Miele, T. Wang, P. N. Williams - Rice University, Houston, Texas

This paper deals with deep-space interplanetary flight to Mars using low-thrust electrical engines. Trajectories optimization is done via the sequential gradient-restoration algorithm (SGRA) for optimal control problems, the controls being the thrust direction _(t) and thrust setting _(t).

The optimization criterion is the minimization of a compromise functional, the linear combination of propellant mass and flight time, appropriately scaled and weighted respectively by the compromise factor C and its complement $1 - C$. In this way, a one-parameter family of optimization problems is obtained. The solutions range from the minimum time trajectory ($C = 0$) to the minimum propellant mass trajectory ($C = 1$). In the middle between the trajectories corresponding to the extreme values of the compromise factor are the compromise trajectories, which occur for $0 < C < 1$. The properties of the compromise trajectories are obtained computationally and discussed.

16:00 AAS 03-578 Optimal Control of a Grey Solar Sail for Interplanetary Missions

G. Colasurdo, L. Casalino – Poli[illegible]ecnico di T[illegible]

Withdrawn

The optimal [illegible] solar sails and the corresponding control laws a[illegible]edure and compared for missions towards eithe[illegible] escape from the solar system, in order to estim[illegible] sail properties on the performance.

16:20 AAS 03-579 Interplanetary Mission Analysis for Non-Perfectly Reflecting Solar Sailcraft Using Evolutionary Neurocontrol

B. Dachwald – German Aerospace Center (DLR)

Solar sailcraft trajectories are typically presented for high-performance sailcraft, assuming that the solar sail is a perfect specular reflector or considering the non-perfect reflectivity through an overall efficiency factor. This limitation and simplification is caused by the drawbacks of traditional variational calculus-based optimizers, for which trajectory optimization for non-perfectly reflecting moderate-performance solar sailcraft is a very difficult optimization problem. Using evolutionary neurocontrol for trajectory optimization, minimal transfer times for non-perfectly reflecting solar sailcraft are presented and it is shown, that a thorough mission analysis must consider the non-perfect reflectivity of the solar sail.

SESSION 11: ATTITUDE DYNAMICS & CONTROL - II

Chair : Don Mackison
University of Colorado

13:30 AAS 03-580 **Attitude Motions of a Spinning Rocket**
F.O. Eke, J. Sookgaew - University of California

This study uses a relatively complex model to analyze the influence of various system parameters on the attitude behavior of a rocket-type variable mass system moving in a torque-free environment. Some of the parameters studied include the system's size, the nozzle expansion ratio, and the location of the propellant within the system's casing. Results obtained indicate that the spin rate as well as the transverse rate can increase, decrease, or stay constant depending on the choice of system parameters. Dramatic changes in the character of these variables can result from relatively minor changes in a rocket's nozzle expansion ratio.

13:50 AAS 03-581 **Optimal Design of a Generalized Three-Dimensional Active Coning Attenuator for a Spinning Spacecraft Under Thrust**
Part II: Criteria for Stability and the Rudiments of an Active Controller.
J. D. Kimball - Oral Robert University

Withdrawn

In a previous paper, a procedure for designing [illegible] optimal three-dim[illegible]al active coning attenuator for a [illegible] ontroller consists of a single [illegible] coning motion, the motion [illegible] stability of the system and [illegible] general equations of motion [illegible] earlier work, we derive some conditions which ou[illegible] parameters must meet to ensure the stability of the system. Furthermore, we consider some relationships which must exist between the various control parameters in order to find a minimum cost for optimal control.

14:10 AAS 03-582 **Attitude Stabilization of an Asymmetrical Rigid Spacecraft Using Two Impulsive Control Torques**
H. Kojima, T. Hashimoto - Tokyo Metropolitan Institute of Technology

A method for reducing the angular momentum of a satellite by giving two-dimensional external impulse torques induced by contact force is proposed, based on the zero dynamics formulation. This method has an advantage in that the contact points are limited. The torque is assumed to be constant during the contact and its magnitude is determined so that the amount during the contact becomes equivalent to the integration of the continuous feedback torque during the contact period. A simulation result shows that the rotational motion is successfully reduced around all axes even if the impulsive torque is two-dimensional.

14:30 AAS 03-583 Analysis of Repetitive Control for Canceling Periodic Measurement Disturbances

R. W. Longman, S. J. Oh - Columbia University

Typical repetitive control is designed to eliminate the influence of periodic disturbances to a control system. However, there is a significant set of engineering applications where instead of a disturbance to the system response, there is a periodic disturbance to the measurement of the response. Spacecraft applications of this kind include the typical sensing of the earth horizons for attitude control in dual spin spacecraft, as well as encoder calibration inaccuracies in precision pointing. In two earlier papers by the authors and co-workers, methods were developed to address this class of problems, creating repetitive control laws that learn to eliminate periodic measurement errors. In this paper, the structure of such new repetitive control laws is contrasted to the structure of the standard repetitive control laws. It is seen that the robustness issue present in the standard problem is not an issue in the new problem. Methods are developed for analyzing stability of the new problem, and the differences are highlighted.

14:50 Break

15:20 AAS 03-584 Prediction of Final Error due to Quantization in Learning and Repetitive Control

R. W. Longman, P. A. LeVoci - Columbia University

Repetitive control is a field that creates controllers that eliminate the effects of periodic disturbances on a feedback control system. The methods have applications in spacecraft problems, to isolate fine pointing equipment from periodic vibration disturbances such as slight imbalances in momentum wheels or cryo pumps. In engineering applications, noise goes into the control algorithm and is acted upon as if it will repeat in the next period, and since it does not repeat, the algorithm amplifies the noise. In a previous paper, the authors presented methods of analyzing the amount of amplification of both plant and measurement noise that will be observed in any given learning algorithm once steady state is reached. However, experiments on a robot at NASA Langley Research Center demonstrated that quantization effects from analog to digital and digital to analog converters, can have a substantial effect on the final error level reached by a repetitive control law. This paper develops methods of analyzing these effects. The limits of the approach are investigated, and it is seen that when there is a reasonable level of white noise from other sources, the statistical assumptions of the approach developed are met, so that they are in fact practical.

15:40 AAS 03-585 Closed-Loop Near-Optimal Slew Control Using Interpolation Polynomials Without Angular Velocity

S. Tanygin - Analytical Graphics

Closed-loop control for a near-optimal slew based on continuously updated 2-point osculating polynomials was recently introduced. This paper employs a similar approach, but modifies it to use only attitude measurements without angular velocity measurements. This eliminates the need to estimate angular velocity for recently proposed gyroless missions equipped with high frequency and high accuracy star trackers. Reference slew trajectory based on Lagrange interpolation polynomials is updated periodically with every attitude measurement. Between the updates, the trajectory is tracked using angular velocity free control law.

16:00 AAS 03-586 18-Degree-of-Freedom Controller Design for the ST7 Disturbance Reduction System

F. L. Markley, P. G. Maghami, M. B. Houghton, O. C. Hsu - NASA Goddard Space Flight Center

The Space Technology 7 experiment will perform an on-orbit system-level validation of a Disturbance Reduction System employing gravitational reference sensors and micronewton colloidal thrusters to maintain a spacecraft's position with respect to freefloating test masses in the gravitational reference sensors to less than 10 nm/√Hz over the frequency range 1 to 30 mHz. This paper presents the design and analysis of the control system that closes the loop between the gravitational reference sensors and the micronewton thrusters while incorporating star tracker data at low frequencies. The effects of disturbances and actuation and measurement noise are evaluated in a eighteendegree-of-freedom model.

16:20 AAS 03-587 Optimal Simultaneous 6 axis Command of a Space Vehicle with a precomputed thruster selection catalogue table

F. Martel - EADS LAUNCH VEHICLES

An efficient on board algorithm is presented determining the optimal jet selection and firing durations for the 6 degrees of freedom command of a space vehicle controlled by fixed thrusters. This method involves a precomputed fixed catalogue table of jet selection and inverse command matrix data preloaded in the flight software not depending on the center of mass. The method applied for the thrusters command in RV of the Automated Transfer Vehicle (ATV) features a reduced on board power processing demand, a feasible table memory size and nice deterministic characteristics for the vehicle design.

SESSION 12: FORMATION FLIGHT-I

Chair : T. Alan Lovell
Air Force Research Laboratory

13:30 AAS 03-588 Design of Spacecraft Formation Flying Orbits
P. M. Bainum, X. Duan - Howard University

This paper presents a method to design relative orbits for spacecraft formation flying and constellation station keeping. The possibility that the relative secular drifts due to the non-spherical Earth's perturbation in the longitude of the ascending node, the argument of perigee and mean anomaly could vanish or be constrained to a desired value is discussed. A general set of solutions is introduced for this problem. Thus, it is possible to choose design parameters to satisfy different requirements for formation flying and constellation station keeping. High precision simulations are conducted to show the effectiveness of the method.

13:50 AAS 03-589 The Insertion of Cloudsat into the A-Train Constellation
M. A. Vincent – Raytheon; C. Salcedo - CNES

The Cloudsat satellite will be flying in a tight formation about 15 seconds in front of the Calipso satellite. Calipso will fly in an independent control box situated behind the control box of the Aqua satellite and in front of one for the Aura satellite. In order to place Cloudsat and Calipso into this configuration a carefully planned Launch and Early Orbit mission design has been created. Starting in a lower Injection Orbit the phasing of catching up with Aqua was analyzed in a probabilistic manner for each day of a 16-day repeating launch day sequence. Taking into account the impulse imparted by the separation spring system and the check-out and calibration maneuvers; the relative positioning of the two spacecraft is analyzed taking into account uncertainties. Finally a sequence of orbit raise and trim maneuvers to the final formation-flying configuration is designed taking into account execution errors.

14:10 AAS 03-590 Sub-Optimal Formation Reconfiguration Scheme Using Impulsive Control
K. T. Alfriend, S. S. Vaddi, S. R. Vadali - TAMU College Station

In this paper we analyze the formation reconfiguration problem. The desired formations are characterized by the orbital elemental differences. Gauss's variational equations are used to compute impulses that establish the desired orbital elemental differences. An analytical, sub-optimal solution is proposed that can be easily implemented. The solution is also extended to the J2 problem. The cost incurred with the analytical solution is found to be close to the cost incurred by the optimal solution obtained by a numerical optimization procedure.

14:30 AAS 03-591 Formation Flying Satellite Control Utilizing Input Shaping
E. Biediger, W. Singhose - Georgia Institute of Technology

The precise control of spacecraft with flexible appendages, such as solar panels or antennas, is extremely difficult. The complexity of this task is magnified many times when several of these spacecraft must be controlled in unison as in formation flying. Formation flying (FF) requires that individual spacecraft in the group execute the desired trajectory while maintaining relative position and velocities with respect to each other. One of the difficulties with formation flying is that the satellites must be autonomous and able to generate and correct their own orbit and attitude profiles without continual guidance from the ground. The objective of the presented work is to enhance the existing formation flying technologies by integrating input shaping techniques. Specifically, input shaping will be used with a decentralized PD formation flying control algorithm.

14:50 Break

15:20 AAS 03-592 An Investigation of Video Tracking on a Formation Flying Satellite Testbed
E. Biediger, W. E. Singhose, D. Frakes - Georgia Institute of Technology ;
M. Kashiwa, S. Matunaga - Tokyo Institute of Technology Tokyo

As the research for formation flying satellites moves from the theoretical arena to the experimental verification stage, video tracking during experiments becomes very important. The size, shape, and color of the marker play a significant role in determining how easily the satellite's position, velocities and attitude are calculated both in real-time and offline. A satellite tracking algorithm was developed to accurately identify the locations of the satellites within the field of view. The image processing system uses colored markers located on the top of the satellites to identify the position. The objective of the work discussed here is to determine the best size, shape, and color for tracking markers that are used on experimental formation flying satellites.

15:40 AAS 03-595 Formationkeeping for Libration Point Missions by Applying Solar Radiation Pressure
H. Li, Trevor Williams - University of Cincinnati

Withdrawn

In this paper, we [illegible] pressure to achieve the for[illegible]cept utilizes solar radiation p[illegible] on libration point satellites, [illegible] point orbits. This method, wh[illegible] approaches, will save considerable propellant and th[illegible] the mission lifetime significantly.

16:20 AAS 03-596 Formation Flight Near L2 in the Sun-Earth/Moon Ephemeris System Including Solar Radiation Pressure

B.G. Marchand, K.C. Howell - Purdue University

The concept of formation flight of multiple spacecraft near the libration points of the Sun-Earth/Moon (SEM) system, offers as many possibilities for space exploration as technical challenges. Previous efforts focused on formationkeeping in the circular restricted three-body problem (CR3BP). In the present study, these results are transitioned into the n-body ephemeris model to incorporate other gravitational perturbations. Solar radiation pressure and model/measurement uncertainties are also included. Discrete and continuous control techniques are both reviewed and successfully applied to multi-spacecraft formations near L2. The rich natural dynamics near the libration points are explored in depth to aid in the development of more complex configurations such as string and spherical formations.

SESSION 13: INTERNATIONAL SPACE STATION
SPECIAL SESSION

Chair : Naz Bedrossian
The Charles Stark Draper Laboratory

08:30 AAS 03-597 ISS Russian GN&C Systems, Verification & Flight Experience Overview
N. Bedrossian - The Charles Stark Draper Laboratory

This paper presents an introduction to the International Space Station Russian propulsive motion control system with regard to controller flex structure dynamic interaction evaluation necessary for flight verification and relevant flight experience. An overview of the Russian GN&C systems and attitude control and reboost operational modes will be provided. Controller flex structure dynamic interaction will be defined and the overall system flex verification process will be described. Verification analysis methods, tools and simulations will also be introduced. Structural flexibility during the ISS assembly process will be reviewed and operational highlights from recent flights presented.

08:50 AAS 03-598 Flex-Controller Interaction During ISS Reboost
E. Griffith, L. Yang - The Charles Stark Draper Laboratory

Due to its large flexible structure, sensed flex motion can interfere with the ISS non-linear closed-loop propulsive Attitude Control System (ACS). The resulting ACS jet-firing commands can resonate flex modes, which increase structural loads and can result in loss of attitude control. Part One of this paper develops the steady-state jet-firing pattern for rigid-Station dynamics. This firing pattern is used to predict peak structural loading. Part Two shows how this firing pattern can be altered by the addition of structural flex. The alteration is caused by a flex modification of the phase plane trajectory and the way it interacts with the switch curves and firing-delay logic. Simulation predictions as well as flight experience will be presented to illustrate flex-controller interaction during ISS reboost.

09:10 AAS 03-599 Attitude Control System Flex Screening
M. C. Johnson - The Charles Stark Draper Laboratory

This paper summarizes analytical techniques used to screen for potential controller flex structure dynamic interaction during attitude holds and maneuvers actuated by the International Space Station Russian propulsive motion control system. An algorithm used to search for attitudes that could result in hold jet firings at frequencies near structural modes will be presented. A procedure will also be presented which determines adaptive filter notch frequencies that could lead to interaction with structural modes during maneuvers, based on filter phase and magnitude response. Examples will be given from pre-flight analyses combining these methods with plant Singular Value Decomposition and non-linear simulation.

09:30 AAS 03-600 Multivariable Modal Gain Factor Model Reduction

J.-W. Jang - The Charles Stark Draper Laboratory

To analyze large dimensional flex models such as the ISS, requires substantial computational effort. The popular Balance and Truncation (B&T) method has been frequently used to reduce computational load. Ironically, the B&T method often requires extensive computational effort and sometimes lacks numerical robustness. In this paper, an innovative technique, which converts a model into a "tri-diagonal modal form" and then truncates the resulting model according to the Modal Gain Factor, is presented. The proposed technique takes less computational efforts and is stable numerically. Comparisons with the B&T method will be presented for various ISS assembly stage flex models.

09:50 Break

10:20 AAS 03-601 ISS Component Models for Dynamics and Controls Analysis

M. Subramaniam - Dynacs

Multi-flexible body models of the International Space Station (ISS) are used to analyze the control-structure interactions of the flexible structure and active control systems during ISS Guidance, Navigation, and Control (GN&C) operations. The multibody models are constructed from finite element (FE) models of individual components or an assembly of components. This paper describes the methods used to adapt the component FE models to accurately model the dynamics of the multibody system. Technical challenges encountered in developing flexible component models from large scale FE models are discussed. Model verification methods to verify the quality of the component FE models as well as the multi-flexible body model are described.

10:40 AAS 03-602 SOMBAT: An Efficient Dynamics and Controls Analysis Tool for Large-Order Flexible Multibody Systems

R. F. Phillips II, M. Subramaniam - Dynacs

The Station/Orbiter Multibody Berthing Analysis Tool (SOMBAT) provides an integrated environment for analyzing the dynamics and control-related issues of complex multibody flexible structures with active control elements. The multibody system can consist of an arbitrary number of rigid or flexible bodies, various types of joints, and several different sensors and actuators. Environmental effects such as atmospheric pressure and gravity gradient can also be included in a SOMBAT model. SOMBAT has been developed to facilitate active control system analysis for the International Space Station (ISS) program. A modified version of SOMBAT has been developed to handle the specific closed loop topology associated with the Mobile Transporter (MT) subsystem of ISS. This paper is composed of two parts. The first part provides an overview of SOMBAT including the multibody formalism, the symbolic code generator that produces the equations of motion in a computationally efficient and optimized form, and the Order (N) recursive solution algorithm. The second part discusses the challenges encountered in dynamic simulation of large scale multibody systems and presents a comparison of SOMBAT's performance on various computer systems.

11:00 AAS 03-603 Draper Station Analysis Tool (DSAT)

J.-W. Jang - The Charles Stark Draper Laboratory

A very low cost, high throughput, scalable, plug-and-play, COTS based simulation development and analysis platform for use in design and verification of complex dynamical systems is reviewed. The tool has been in continuous use over the past 5 years for integrated verification of the ISS GN&C systems, while meeting demanding schedules and providing confidence in risk estimates. Its modular design accommodates parameter or architecture modifications. Its unique features include automated simulation generation, verification analysis process, and results documentation. Its functional capabilities include analytic, frequency domain, and time domain analysis. The tool’s full functional capabilities are also accessible via the Web (http://www.jsc.draper.com/esim).

11:20 DSAT Demo

J.-W. Jang - The Charles Stark Draper Laboratory

In this session, demonstrations of the DSAT tool will be provided. Its functional capabilities will be demonstrated as well as its use in ISS GN&C systems flex verification process. Demonstrations will be provided for dynamic scaling, automated simulation generation, automated analytic and frequency domain analysis, automated results documentation, flex model reduction, flex model simulation, and Web access.

SESSION 14: ATTITUDE DETERMINATION, SYSTEM IDENTIFICATION

Chair : Mark Pittelkau
JHU Applied Physics Laboratory

08:30 AAS 03-604 Pseudo Linear Gyro Calibration

R. Harman – NASA Goddard Space Flight Center; I. Y. Bar-Itzhack - Technion-Israel Institute of Technology

This paper builds upon previous attitude, rate, and specialized gyro parameter estimation work performed with Pseudo Linear Kalman Filter (PSELIKA) [3]. The PSELIKA advantage is the use of the standard linear Kalman Filter algorithm. A PSELIKA algorithm for an orthogonal gyro set which includes estimates of attitude, rate, gyro misalignments, gyro scale factors, and gyro bias is developed and tested using simulated and flight data. The used PSELIKA measurements include gyro and quaternion tracker data.

08:50 AAS 03-605 Testing of Gyroless Estimation Algorithms for the FUSE Spacecraft

R. Harman, J. Thienel - NASA Goddard Space Flight Center; Y. Oshman - Technion-Israel Institute of Technology

The Far Ultraviolet Spectroscopic Explorer (FUSE) is equipped with two ring laser gyros on each of the spacecraft body axes. In May 2001 one gyro failed. It is anticipated that all of the remaining gyros will also fail, based on intensity warnings. In addition to the gyro failure, two of four reaction wheels failed in late 2001. The spacecraft control now relies heavily on magnetic torque to perform the necessary science maneuvers and hold on target. The only sensor consistently available during slews is a magnetometer. This paper documents the testing and development of magnetometer-based gyroless attitude and rate estimation algorithms for FUSE. The results of two approaches are presented, one relies on a kinematic model for propagation, a method used in aircraft tracking, and the other is a pseudo-linear Kalman filter that utilizes Euler's equations in the propagation of the estimated rate. Both algorithms are tested using flight data collected over a few months before and after the reaction wheel failure. Finally, the question of closed-loop stability is addressed. The ability of the controller to meet the science slew requirements, without the gyros, is tested through simulations.

09:10 AAS 03-606 Attitude Determination Algorithm for Gyroless Spacecraft Using Optimal Disturbance Accommodation Technique

I. Kim - Seoul National University; J. Kim - Swales Aerospace; Y. Kim - Seoul National University

Several attitude determination algorithms for a gyroless spacecraft have been proposed for the last few decades. In this paper, we propose a new approach to estimate the angular rate of this spacecraft. We divide the true angular rate into two parts, namely, the known reference rate and the unknown residual rate. Then this residual rate can be approximated as a linear combination of known basis functions. The optimal disturbance accommodation technique estimates the approximated residual rate by using the optimization technique. For verification, we apply this technique to the attitude determination system with the only two star trackers.

09:30 AAS 03-607 Autonomous Star Tracker Development for the New Horizons Mission

D. R. Haley, T. E. Strikwerda, K. A. Ailinger - JHU Applied Physics Laboratory;
R. Casini, A. Landi, R. Bettarini - Galileo Avionica

The New Horizons mission to Pluto and the Kuiper Belt is scheduled for launch in early 2006. Overall mission design requires a star tracker that operates autonomously both in a standard "staring" mode and in a spin stabilized mode. With the support of APL and the New Horizons Program, Galileo Avionica has redesigned the software for their ASTR star tracker to use time-delayed integration techniques (TDI) to provide autonomous spacecraft attitude estimates at 4 Hz. or faster and at spacecraft body rates up to 10 RPM. This paper will present an overview of the mission and the design considerations and operating modes for the modified ASTR tracker, as well as expected accuracy performance.

09:50 Break

10:20 AAS 03-608 Toward Ground-Based Autonomous Telescope Attitude Estimation Using Real-Time Star Pattern Recognition

C. Bruccoleri, D. Mortari, T. C. Pollock, J. L. Junkins - Texas A&M University

Star Sensors are widely used to estimate spacecraft attitude with respect to an inertial reference frame. These instruments use the stars as a reference for the attitude estimation, thus it requires the integration of a camera, for star image acquisition, and an on board computer for image processing, and attitude estimation. Because of the constraints imposed by the space environment and the small number of units sold these are very expensive. However, due to recent advances it is possible to build such an instrument for routine use with Earth-based telescope and camera observation. This can be realized using inexpensive off-the-shelf hardware components. Thus, a professional or amateur astronomer could add to his set of tools an instrument that automatically calculates the attitude of the camera with respect to the local site, and knowing the attitude of the camera with respect to the equatorial mount, and thereby lay the basis for an autonomous system capable of aligning the equatorial mount, before the beginning of the observation session. This advance will make amateur astronomy more accessible because the telescope set-up will be essentially automated and all stars in the camera view will be automatically identified.

10:40 AAS 03-609 Novel Techniques For The Creation of a Uniform Star Catalog

M. A. Samaan, C. Bruccoleri, D. Mortari, J. L. Junkins - Texas A&M University

In order to develop the theory that justifies the adoption of a specific Star Identification Algorithm for a Star Sensor, and also to make this algorithm more reliable in the region of the sky with lower star density, the problem of building an uniform star catalog aroused. By uniform star catalog we mean that pointing at a region of the sky determined by the FOV of the camera, a certain number of stars (i.e. 5) is always seen, with a small standard deviation. In this paper we present four novel techniques for creating a uniform star catalog. These methods mainly depend on creating a uniform distribution of vectors around the surface of a unit sphere. In the first method we divide the unit sphere into large number of *Spherical Squares* which have the same area. The second is to create a fixed slope *Spiral* around the unit sphere and then divide it into segments of the same length. Another method uses the idea of randomly distributing the points on the unit sphere and then letting the particles act as electrically charged, as if there is repulsive force that tends to uniformly distribute the points on the sphere. The last method uses a recursive approach that divides the sphere in non-overlapped *Spherical Triangles*.

11:00 AAS 03-610 Experimental Demonstration of an Algorithm to Detect the Presence of a Parasitic Satellite

V. J. Dabrowski, R. G. Cobb - Air Force Institute of Technology

Published reports of microsatellite weapons testing have led to concern that some of these "parasitic" satellites could be deployed against US satellites to rendezvous, dock and then disrupt, degrade, disable, or destroy the system. An effective detection method is essential. Various sensing solutions were investigated including visual, impact, and dynamic techniques. Dynamic detection, the most effective solution, was further explored. A detection algorithm was constructed and validated on the Air Force Institute of Technology's ground-based satellite simulator. Results indicate that microsatellites rigidly connected to a satellite can be detected with a series of small, identical, maneuvers utilizing data available today.

11:20 AAS 03-611 Comparison of System Identification Techniques for a Spherical Air-Bearing Spacecraft Simulator

J. Schwartz, C. D. Hall – Virginia Polytechnic Institute & State University

Virginia Tech is developing a Distributed Spacecraft Attitude Control System Simulator (DSACSS), which includes two independent spherical air-bearing platforms for formation flying attitude control simulation. The DSACSS is intended to support a wide range of functions, so requiring that all controllers be robust to approximations of the system parameters is impractical. We document the process to determine an appropriate system identification technique for an air-bearing spacecraft simulator. We consider many techniques, including linear least squares, the Extended Kalman Filter, and higher-order nonlinear filters such as the Unscented Kalman Filter. We investigate the relationship between accuracy and computation time.

SESSION 15: AUTONOMOUS GNC SYSTEMS

Chair : Al Treder
Dynacs Engineering Co.

08:30 AAS 03-612 **Autonomous Slew Manoeuvring and Attitude Control Using the Potential Function Method**

M. Casasco, G. Radice - University of Glasgow

This paper analyses and compares two different attitude representations (using quaternions and modified Rodrigues parameters) in the context of the potential function method applied to autonomously control constrained attitude slew manoeuvres. This method hinges on the definition of Lyapunov potential functions in terms of the attitude parameters representing the current attitude, the goal attitude and any pointing constraints, which may be present. This method proves to be successful in forcing the satellite to achieve the desired attitude while avoiding the pointing constraints. Finally advantages and drawbacks of both attitude representations are discussed.

08:50 AAS 03-613 **Hardware Development and Measurements of Solar Doppler Shift for Spacecraft Orbit Determination**

T. A. Henderson, T. C. Pollock, A. J. Sinclair, J. E. Theisinger, J. E. Hurtado, J. L. Junkins - Texas A&M University

Autonomous spacecraft navigation throughout our solar system can be achieved by using the Sun as a navigation reference body. This allows a self-contained navigation system to guide a spacecraft into any orbit in the solar system, with no need for ground support. A key to developing such a system is knowledge of radial velocity relative to the Sun. The current development of hardware to perform the measurements, current measurement results, and future research plans will be discussed in detail. The associated orbit determination algorithm will also be discussed.

09:10 AAS 03-614 Autonomous Landmark Tracking Orbit Determination Strategy
J. K. Miller, Y. Cheng - Jet Propulsion Laboratory

Determination of the orbit of a spacecraft about an asteroid or comet presents many challenges relating to the dynamic environment and introduction of new data types. Optical tracking of craters on the surface of a central body was first used operationally for navigation by the Near Earth Asteroid Rendezvous (NEAR) mission to the asteroid Eros. The NEAR navigation system relied on a manual system of landmark detection and identification. Development of an autonomous navigation system would require orbit determination to be performed on the spacecraft computer with no human intervention. In this paper, an orbit determination strategy is described that is fully autonomous and relies on a computer-based crater detection and identification algorithm that is suitable for both automation of the ground based navigation system and autonomous spacecraft based navigation.

09:30 AAS 03-615 Impactor Spacecraft Targeting for the Deep Impact Mission to Comet Tempel 1
D. G. Kubitschek - Jet Propulsion Laboratory

The engineering goal of the Deep Impact mission is to impact comet Tempel 1 on July 4, 2005, with a 350 kg active Impactor spacecraft (s/c). Deep Impact will use the autonomous optical navigation (AutoNav) software and the Impactor Targeting Sensor (ITS) to guide the Impactor to intercept in an illuminated area, while a second s/c points a High Resolution Instrument (HRI) and Medium Resolution Instrument (MRI) at the impact site. This paper describes the Impactor s/c autonomous targeting approach including the image processing and navigation, and assesses the Impactor s/c performance based on Monte Carlo analyses and MATLAB simulations.

09:50 Break

10:20 AAS 03-616 The Design of the Guidance, Navigation and Control System for an Inspection and Rendezvous Spacecraft
R. R. Fullmer, R. Pack - Utah State University;
P. Patterson - Space Dynamics Laboratory

Large constellations of satellites may require a set of small, inexpensive satellites for inspection and repair. These maintenance spacecraft will have the ability to visually inspect and rendezvous with constellation satellites to replace consumable resources. These inspection spacecraft need to be able to operate in extended close proximity about a damaged and potentially nonoperational spacecraft. This paper describes the conceptual development of the guidance, navigation and control (GNC) system of an autonomous spacecraft that can perform an on-orbit rendezvous and extended proximity operations required by an inspection mission.

10:40 AAS 03-617 Autonomous Guidance and Control of an Earth Observation Satellite Using Low Thrust

J. de Lafontaine, I. Jean – Université de Sherbrooke

Earth observation satellites are typically placed into low Sun-synchronous orbits. In order to maintain certain desired orbital characteristics, orbit control may be necessary to offset air drag and other perturbations. A modification of the nominal orbit may also be required so particular terrestrial targets of interest can be revisited more often, or can be observed with a more favorable viewing geometry. To maintain or modify an orbit, the high mass efficiency of electric propulsion is an attractive solution. Its low thrust level and resulting long-term effects on the orbit require significant orbital guidance in order to apply control effectively. In a continuation to our past developments in spacecraft autonomy, this paper presents techniques for the autonomous guidance and control of an Earth-observation satellite orbit using low thrust, with the objective of maintaining a reference orbit or modifying it to overfly given terrestrial targets.

11:00 AAS 03-618 Global Precipitation Measurement (GPM) Orbit Design and Autonomous Maneuvers

D. Folta, C. Mendelsohn - NASA Goddard Space Flight Center

The NASA GSFC's Global Precipitation Measurement (GPM) mission will meet a challenge of measuring worldwide precipitation every three hours. Analysis has shown that a 407km circular orbit with frequent maneuvers is necessary. An autonomous maneuver system will minimize maneuver impacts to science data collection and enabling long-term predictions. This paper presents the driving science requirements and goals of the mission and shows how they will be met. Analysis of the orbit optimization, ΔV requirements and the architecture of the autonomous maneuvering system are presented along with simulations using a prototype. Use in collision avoidance and navigation is addressed.

11:20 AAS 03-619 The Use of X-ray Pulsars for Spacecraft Navigation

S. I. Sheikh - University of Maryland; P. S. Ray, K. S. Wood, M. N. Lovellette, M. T. Wolff - Naval Research Laboratory

Withdrawn

The use of X-ray pulsars in determining full navigation information for a spacecraft is investigated. With their unique, periodic, [illegible] stable signals, X-r[illegible] provide a specialized [illegible] ption of X-ray pulsar[illegible] given. A brief history [illegible] ption of the on-orbit [illegible] Laboratory. An overview of [illegible] presented, which is capable of determining [illegible] position, velocity, and attitude. Simulated results are presented and compared to USA experiment orbit information.

SESSION 16: NEUTRAL DENSITY AND SATELLITE DRAG
SPECIAL SESSION

Chair : Frank Marcos
Air Force Research Laboratory

13:30 AAS 03-620 Satellite Drag Research: Past, Present and Future

F. A. Marcos, J. O. Wise - Air Force Research Laboratory, M. J. Kendra – Radex; N. Grossbard - Boston College

Uncertainties in neutral density variations continue to be the major source of satellite drag errors. From early in the space age to almost the end of the twentieth century there was essentially no progress in satellite drag modeling capabilities. This century has already shown significant advances in areas of new measurements, models, solar proxies and data assimilation techniques. We review some of the operational impacts of satellite drag and current and future capabilities to deal with evolving higher accuracy requirements. There has been a resurgence of research activity involving orbital drag analyses. We describe contributions of our satellite drag database to identifying missing physics, new model and proxy capabilities and unmodeled long-term changes in thermospheric density.

13:50 AAS 03-621 Atmospheric Density Measurements Derived from CHAMP/STAR Accelerometer Data

R. S. Nerem, J. M. Forbes, E. Sutton - University of Colorado; S. Bruinsma - CNES/GRGS

The STAR accelerometer on-board the German CHAMP satellite has provided precise global (+/- 87 degrees latitude) measurements of non-gravitational accelerations at ~450 km altitude since its launch in July 2000. We will present our method for deriving atmospheric densities from these data, compare the observed densities to several atmospheric density models, and analyze the derived densities by binning as a function of season, latitude, local time, etc.

14:10 AAS 03-622 Early Results from the Gravity Recovery and Climate Experiment
B. D. Tapley - The University of Texas

Mass transport between the earth's atmosphere, oceans and solid earth is a critical component of global climate change processes. Mass change is an important component of the signals associated with global sea level and polar ice mass change, depletion and recharge of continental aquifers, and change in the deep ocean currents. This mass exchange has a gravitational signal, which can be monitored as an indication of the process. The Gravity Recovery and Climate Experiment (GRACE) is a dedicated satellite mission whose objective is to map the global gravity field with unprecedented accuracy over a spatial range from 400 km to 40,000 km every thirty days. The measurement precision will provide a mean gravity field whose accuracy in this frequency range is between 10 and 1000 times better than our current knowledge The results are applicable to studies of the general ocean circulation and ocean-atmosphere heat and mass exchange. Measurements of continental aquifer mass change, polar ice mass change and ocean bottom currents are examples of a completely new remote sensing capability whereby we can use satellite measurements to look into the earth's interior.

14:30 AAS 03-623 Preliminary Validation of Atmospheric Neutral Density Derived from Ultraviolet Airglow Observations
A.C. Nicholas, S.E. Thonnard, J.M. Picone, K.F. Dymond, S.A. Budzien - Naval Research Laboratory; S.H. Knowles - Raytheon Technical Corp.; S.M. McCoy, E.E. Henderlight - Praxis Inc.; R.P. McCoy - Office of Naval Research

Climatological atmospheric density models used for orbit determination and prediction have errors that range from 10% to 15%. For Low Earth Orbiting (LEO) satellites, the error due to an imprecise density specification is the most significant contribution to the error ellipse associated with the position of the object. This paper presents ultraviolet airglow derived atmospheric density corrections for the NRLMSISE-90 model during January and February 2001. Preliminary validation of the improved density specification is provided through comparisons to existing climatological models, a data driven atmospheric model and total density derived from satellite drag.

14:50 Break

15:20 AAS 03-624 A Long-term Decrease in Thermospheric Density Derived from Historical Orbital Elements

J. T. Emmert, J. M. Picone, J. L. Lean - Naval Research Laboratory;
S. H. Knowles - Raytheon Technical Services at NRL

We derive secular trends in upper atmospheric density using historical orbital elements of 32 long-lived, near-Earth space objects. Our results indicate a long-term decrease in density of 2.5-3% per decade at a height of 400 km. The magnitude of this decrease is comparable to that of theoretical predictions of the effect of increased greenhouse gas concentrations; greenhouse gases are effective emitters of infrared radiation and should cause the upper atmosphere to cool and contract. Our observed trends increase with increasing height and geomagnetic activity, but are largely independent of solar activity, season, latitude, and local time.

15:40 AAS 03-625 High Accuracy Satellite Drag Model (HASDM) Review

B. R. Bowman - Air Force Space Command; W. K. Tobiska - Space Environment Technologies

The dominant error source in force models used to predict low altitude satellite trajectories is atmsopheric drag. Upper atmospheric density models do not adequately account for dynamic changes in neutral density, leading to significant errors in predicted satellite positions. The Air Force has developed a High Accuracy Satellite Drag Model program that computes “real time” upper atmospheric neutral density variations using ~80 calibration satellites in a wide range of orbit inclination and perigee heights ranging from 200km to 800km. The HASDM program estimates a set of density correction coefficients every 3 hours as a function of latitude, local solar time, and altitude. A time series filter then predicts (out three days) the density correction parameters as a function of predicted extreme ultraviolet (EUV) energy index $F_{10.7}$ and predicted geomagnetic storm index a_p. The estimated and predicted density fields are then use to first differentially correct all the drag influenced orbits (over 6000) in the NORAD catalog, and then predict all satellite trajectories out three days. A six month demonstration period was conducted in 2001, where the concept was validated using data from ~120 satellites. The resulting improvements in epoch accuracy, ballistic coefficient consistency, and predicted positions led to a full drag catalog 60 day test in 2002. The excellent results from the full drag catalog test are leading to an operational implimentation of the HASDM program sometime in 2004.

16:00 AAS 03-626 Atmospheric Density Correction Using Two Line Element Sets as the Observation Data

P. J. Cefola - MIT/Lincoln Lab; R. J. Proulx – CS Draper Lab; A. I. Nazarenko – Center for Program Studies, Moscow; V. S. Yurasov - Kosmos

Corrections to the GOST Atmosphere Density Model are derived from the Two Line Element (TLE) set data. The density correction includes a bias term and one linear with the altitude. Density corrections are constructed on a one day grid. The input to the construction process is the daily TLE sets for 300 to 500 drag-perturbed space objects, the observed solar flux, and the geomagnetic data. Each TLE is converted to a 'noisy' single-averaged element set by adding the long period perturbations. Then several 'noisy' single-averaged element sets are least-squares fit with the USM semianalytical satellite theory with the GOST density model. This results in a smoothed USM element set and associated ballistic factor. The density corrections are generated from the smoothed ballistic factors resulting from the secondary data processing. The secondary data processing is repeated with the corrected GOST density model. The fit and predict results with the uncorrected and corrected density models are compared. The process is demonstrated over a 10-month interval from April 2002 through January 2003. The ballistic factor for the Starshine 3 spherical satellite with the iterated secondary processing closely matches the theoretical value.

16:20 AAS 03-627 On the Use of Physics-Based Models in Data Assimilation for Neutral Density Specification and Forecast

T. Fuller-Rowell, C. Minter, M. Codrescu - CIRES University of Colorado and NOAA Space Environment Center

The value of physical models as Kalman state propagators is that they can capture the time-dependent response to geomagnetic events, including the propagation of neutral density waves and the development of deep density holes. If sufficient observations are available to specify the current conditions and initialize the physical model, a short-term forecast is feasible. The challenge is to define accurate spatial and temporal variations of the geomagnetic sources at high latitudes to drive the model. The best approach is to include the model drives in the Kalman state and optimize the model forcing as well as the initial conditions.

16:40 AAS 03-628 Localized Atmospheric Density Model Validation Using High Eccentricity Satellite Observations

K. Akins , L. Healy - Naval Research Laboratory

Atmospheric density models may be validated with satellite orbits if sufficiently precise observations, such as those from laser ranging, are available. To validate local models, one needs local information. Using a near-circular orbit for validation, however, yields drag information averaged over time and space. A satellite with high eccentricity provides desired localization, as it experiences measurable drag only for a brief time near perigee. The Japanese LRE with eccentricity 0.73 and laser retro-reflectors provides an ideal candidate for testing local atmospheric density models. In this paper we present the results of a validation study using this satellite.

17:00 AAS 03-629 The Behavior of the Upper Atmosphere During Solar/Geophysical Storm Conditions As Measured By Satellite Drag During The Entire Space Age

S. H. Knowles - Raytheon Technical Services Corp. and Naval Research Laboratory; S.H. Thonnard, A.C. Nicholas - E.O. Hulburt Center for Space Research

The orbits of 32 space objects have been examined for a period covering 1961 to present. A simple two-parameter model has been used to convert the inverse ballistic coefficients at different altitudes to a daily 'drag-determined' atmosphere. These determinations are validated by samples of atmospheric density determined by the LORAAS ultraviolet spectrograph. The solar storms during the current solar cycle are of similar magnitude to the well-known 1989 storm. Exceedance vs time span curves are generated for environmental guidance.

SESSION 17: ORBIT CONTROL, ORBITAL TRANSFERS - II

Chair : Bobby G. Williams
KinetX

13:30 AAS 03-630 A Simple Control Law for Low-Thrust Orbit Transfers

A. E. Petropoulos – Jet Propulsion Laboratory

A method is presented by which to determine both a thrust direction and when to apply thrust to effect specified changes in any of the orbit elements except for true anomaly, which is assumed free. The central body is assumed to be a point mass, and the initial and final orbits are assumed closed. Thrust, when on, is of a constant value, and specific impulse is constant. The resulting thrust-profile is not optimal, but is based firstly on the optimal thrust directions for changing each of the orbit elements and secondly on the desired changes in the orbit elements. The control law has few input parameters, but can still capture the complexity of a wide variety of orbit transfers.

13:50 AAS 03-631 Solar Electric Propulsion System Sensitivity to Thruster Isp Variation

M. Cupples, S. Green - Science Applications International Corporation;
V. Coverstone, J. W. Hartmann - University of Illinois at Urbana

Investigation of two thruster models, NASA's Evolutionary Xenon Thruster (NEXT) and the NASA NSTAR-3 thruster, showed the impact that ion thruster Isp variation has on predicted Solar Electric Propulsion System (SEPS) payload and transfer time. Detailed SEPS subsystem models and a set of optimized Earth-Venus-Neptune trajectories provided the framework for vehicle performance computations. Mission, launch vehicle, power, and propulsion system assumptions (including contingencies/redundancies) will be presented. Results presented will include optimized trajectories, SEPS payload versus transfer time, engine-on time history, and Isp time history.

14:10 AAS 03-632 Optimal Low-Thrust Supersynchronous-to-Geosynchronous Orbit Transfer

B. A. Conway, C. Chilan - University of Illinois at Urbana

A method currently used for low-Earth orbit to geosynchronous orbit transfers, for example by the Boeing 702 series spacecraft, utilizes a supersynchronous injection orbit that is then circularized by applying electric thrusters in an inertially fixed direction. In this work, an optimal (minimum-flight-time) trajectory for a supersynchronous-to-geosynchronous orbit transfer is found. In the optimal low-thrust transfer to the final GEO the thrust is no longer applied in a fixed direction. The thrust acceleration and engine performance is characteristic of electric propulsion systems. Since the electric motor operates continuously a minimum-time transfer, i.e. minimum-time circularization, is also propellant-minimizing. The flight times for the optimal trajectory and for the trajectory using inertially fixed thrust are compared.

14:30 AAS 03-633 Transfers to and Station-keeping of Restricted Three Body Trajectories with Low Thrust Propulsion

J. Senet, C. Ocampo, A. Capella - The University of Texas at Austin

The use of low thrust engines to transfer a vehicle from the smaller primary to an arbitrary circular restricted three body trajectory and subsequent station-keeping along this trajectory is investigated. As a practical application we consider the transfer of a spacecraft from a low Earth orbit to an unstable libration point orbit at either the interior or exterior collinear libration points near the Earth in the Sun-Earth system. Optimal control, nonlinear state feedback control, and dynamical systems theory are used solve both mission phases. A unified procedure is developed that facilitates the construction of these solutions for more general classes of target orbits and realistic force models.

SESSION 18: CONSTELLATION DESIGN & COVERAGE ANALYSIS

Chair : Ron Proulx
The Charles Stark Draper Laboratory

15:20 AAS 03-634 Design and Analysis of a Small Constellation of Satellites for Mid-Course Tracking

I. A. Budianto, D. Gerencser - USAF Research Laboratory;
P. J. McDaniel - Sandia National Laboratories

A methodology employing Genetic Algorithm was developed to design a small constellation of mid-course surveillance satellites. The objective was for the space-based system to intercept an arc of the missile trajectory to be handed over to other defensive elements. A continuous coverage of the moving point is not required. The solution to this problem is highly dependent on the threat scenario considered. For the chosen test scenario, as few as two satellites were able to accomplish the objective, resulting in an acceptable maximum gap and percent coverage. Sensitivity analyses show robustness of the solutions to off-nominal missile trajectories.

15:40 AAS 03-635 Interferometric Observatories in Circular Orbits: Designing Constellations for Capacity, Coverage and Utilization

V. G. Rao, P. T. Kabamba - University of Michigan

In this paper we present an original technique for selecting constellation geometries for multi-spacecraft interferometric observatories to meet three mission objectives: capacity, coverage and utilization. The technique poses the problem as a constraint satisfaction problem involving both geometric and scheduling constraints for the mission design. Results are presented concerning tradeoffs among the three objectives. In particular, we show that for a given coverage requirement, there exists a tradeoff between capacity and utilization. The design procedure is illustrated with several examples.

16:00 AAS 03-636 Globalstar™ Constellation Design and Establishment Experience

A. E. Turner, J. J. Rodden, M. Tse - Space Systems/Loral

This paper discusses the concepts used during the recently completed development of the Globalstar™ constellation. This system includes 52 spacecraft on orbit, 48 are generating revenue through delivery of satellite telephony and 4 are on-orbit spares; all spacecraft launched are still in commercial operation.

16:20 AAS 03-637 Tundra Constellation Mission Design and Stationkeeping

H. J. Pernicka - University of Missouri-Rolla;
M. J. Bruno - San José State University

The geostationary orbit belt has become highly populated with communication satellites, making frequency allocations more challenging to obtain. An innovative solution to this problem may be provided by the recently proposed Tundra orbit constellation. The Tundra constellation uses three or more spacecraft in inclined geosynchronous orbits. The needed terrestrial coverage is obtained by proper orientation of each orbit relative to the constellation and by proper phasing of each satellite within its orbit. The nominal orbit design for the constellation must minimize any negative perturbation effects in order to provide affordable stationkeeping costs. This study describes a study of the Tundra constellation given basic constraints. Mission design elements are first considered followed by a discussion of stationkeeping issues. Perturbation effects from third-body and geopotential sources are quantified and used to select nominal orbits that will provide the needed coverage and that can be maintained within reasonable fuel budgets.

16:40 AAS 03-638 Applications of Ergodic Theory to Coverage Analysis

M. W. Lo - Jet Propulsion Laboratory

The study of differential equations, or dynamical systems in general, has two fundamentally different approaches. We are most familiar with the construction of solutions to differential equations. Another approach is to study the statistical behavior of the solutions. Ergodic Theory is one of the most developed methods to study the statistical behavior of the solutions of differential equations. See Sinai (Ref. 1) and Arnold (Ref. 2) for references and an introduction to this field. In the theory of satellite orbits, the statistical behavior of the orbits is used to produce "Coverage Analysis" or how often a spacecraft is in view of a site on the groud. In this paper, we consider the use of Ergodic Theory for Coverage Analysis. This allows us to greatly simplify the computation of quantities such as the total time for which a ground station can see a satellite without ever integrating the trajectory, see Lo (Ref. 1, 2). More over, for any quantity which is a function of the ground track, its average may be computed similarly without the integration of the trajectory. For example, the data rate for a simple telecom system is a function of the distance between the satellite and the ground station. We show that such a function may be averaged using the Ergodic Theorem.

SESSION 19: AEROCAPTURE, ATMOSPHERIC ENTRY

Chair : Daniel T Lyons
Cal-Tech Jet Propulsion Laboratory

13:30 AAS 03-639 Low-Thrust Guidance Scheme for Earth-Capture Trajectories

C. A. Kluever, Y. Gao - University of Missouri-Columbia

A feasible guidance scheme for the Earth-capture phase of a low-thrust spacecraft is developed. The objective of the guidance scheme is to provide the appropriate thrust steering program that will transfer the vehicle from hyperbolic conditions near the Earth's sphere of influence to a circular low-Earth orbit. Blending two control laws that reduce energy and eccentricity, respectively, generates the steering angle commands. Our guidance design is predictive in nature, and the algorithm iterates on a single guidance parameter (a blending coefficient) such that a performance measure is minimized and boundary conditions are satisfied. Numerical simulations of guided capture trajectories are presented.

13:50 AAS 03-640 Evaluating Trajectories for a Feasible Earth-Orbit Aerocapture/Aerogravity Assist Demonstration

T. J. Mosher, B. A. Moffitt - Utah State University

Aerocapture and aerogravity assist are two important space flight approaches that once demonstrated can enable or enhance several planned planetary missions. However, because there is risk inherent in each of these methods, the NASA New Millennium program has considered a flight demonstration. The New Millennium baseline approach is to put a spacecraft into a geosynchronous transfer orbit and perform the experiment by increasing the Earth approach velocity to simulate the high velocity conditions of an aerocapture or aerogravity assist entry. As an alternative, a mission is analyzed that uses the Moon's gravity to increase the velocity via a lunar swing-by.

14:10 AAS 03-641 CNES re-entry experience at service of ASTRA 1K deorbitation

L. Francillout, J.F. Goester - Centre National d'Etudes Spatiales (CNES)

On November 25, 2002, CNES Flight Dynamics teams had to face a critical situation. Proton launch of the telecommunication satellite ASTRA 1K failed and the satellite was released on an orbit of 175 km altitude and 51 degree inclination which should have lead to a reentry within 3 or 4 days. The decision to de-orbit the satellite has been then taken by SES ASTRA and the operations have been performed by the CNES teams. Reentry successfully took place early on December 10, 2002. The paper presents how the CNES re-entry experience has been used to deorbit ASTRA-1K and how it influences now the ATV deorbitation design.

14:30 AAS 03-642 **Mars Exploration Rover Six-Degree-of-Freedom Entry Trajectory Analysis**

P. N. Desai, M. Schoenenberger, F. M. Cheatwood - NASA Langley Research Center

The Mars Exploration Rover mission will send two Landers to the surface of Mars, arriving in January 2004. Both Landers will deliver the rovers to the surface using an entry, descent, and landing (EDL) scenario based on Mars Pathfinder heritage. However, the entry conditions and environments are different from that of Mars Pathfinder. Unique challenges are present due to the entry differences of a higher entry mass and less dense atmosphere profile. This paper describes the hypersonic six degree-of-freedom trajectory analysis of the entire entry (from cruise-stage separation to parachute deployment) to predict the descent attitude and deploy conditions during the descent. In addition, a Monte Carlo dispersion analysis is performed to ascertain the impact of off-nominal conditions that may arise during the entry to determine the robustness of the MER capsule design.

14:50 Break

15:20 AAS 03-643 **Approach Navigation for a Neptune Aerocapture Orbiter**

R.J. Haw - Jet Propulsion Laboratory

The Neptune Aerocapture mission will use solar electric propulsion to send an orbiter to Neptune . The delivery of this spacecraft and two probes to Neptune is analyzed in order to demonstrate the feasibility of direct-entry aerocapture techniques for orbit insertion.

15:40 AAS 03-644 **An Investigation of Titan Aerogravity Assist for Capture into Orbit About Saturn**

J. E. Lyne, P. Ramsey - The University of Tennessee

While aerocapture has often been found to be feasible using vehicles with low to moderate lift-to-drag ratios, aerogravity assist (AGA) maneuvers are typically believed to require extremely high values of the L/D. Such high lift-to-drag ratios require relatively sharp-nosed vehicles that are not currently feasible because of the severe convective heating rates that result. The present study considers an application of AGA that would not require a high L/D, and, therefore, may be more feasible using near-term technology. We propose that an AGA maneuver using the moon Titan could capture a spacecraft into orbit about Saturn, using a modest L/D aeroshell. This method is more appealing than capturing directly at Saturn because of the lower entry speeds and less severe aerothermal heating.

16:00 AAS 03-645 Preliminary Analysis of Uranus Aerocapture

J.E. Lyne, P. Ramsey, C. Ott, B. Weber, C. Moreno-Rivera - The University of Tennessee

This paper presents an analysis of aerocapture options at Uranus. Vehicle configurations similar to those previously considered for use at Neptune were evaluated. Aerodynamic entry corridor widths were evaluated as a function of atmospheric entry velocity, target orbit apoapse altitude and vehicle aerodynamics. In general, corridors were found to be quite wide and deceleration loads modest; it appears that low lift-to-drag configurations may be suitable for this mission.

16:20 AAS 03-646 Ballute Aerocapture Trajectories at Titan

D. T. Lyons - Jet Propulsion Laboratory

Aerocapture at planets and moons with atmospheres using a towed, inflatable ballute system has the potential to provide significant performance benefits compared to traditional all propulsive and aerocapture technologies. This paper discusses the characteristics of entry trajectories for ballute aerocapture at Titan. These trajectories are the first steps in a larger systems analysis effort that is underway to characterize and optimize the performance of a ballute aerocapture system for future missions to Titan.

16:40 AAS 03-647 Performance Analysis of Re-Entry Flight System for the Typical Uncertainties

D.-W. Lee, K.-R. Cho - Pusan National University

The Monte-Carlo simulation of statistical analysis is used to investigate the final conditions of states as well as the footprint boundaries resulting from the atmospheric re-entry dispersions. The re-entry dispersions in this paper are specified by a 7x7 covariance matrix of latitude, longitude, altitude, bank angle, flight path angle, heading error, and range at entry velocity. The error sources that affect these at re-entry for a deboost are the uncertainties associated with initial errors of each states, atmospheric density, temperature, wind, and estimation error of aerodynamic coefficients. Major considerations in the application of the Monte-Carlo method into the re-entry flight system are the simulation of perturbed trajectories, bank reversal, and determination of the impact points for each of these trajectories. This paper analyzes the results of uncertainties from the viewpoint of aero-coefficients and bank reversal.

SESSION 20: FORMATION FLIGHT - II

Chair : Dan Scheeres
The University of Michigan

08:30 AAS 03-648 Genetic Algorithm Based Sliding Mode Control in the Leader/Follower Satellites Pair Maintenance

Y. Xu, N. Fitz-Coy - University of Florida; P. A. C. Mason – Goddard Space Flight Center

Since 1977, when Utkin first proposed Variable Structure Systems (VSS) and Sliding Mode Control (SMC), the sliding mode control has attracted interest in the control theory and application worldwide [4]. Recently, sliding mode control has been adopted for the formation flight system [6]. The advantages of the sliding mode control include uncertainties' rejection and convenience for designing nonlinear controllers. Nevertheless, there are two major disadvantages for the very first sliding mode control. One is the chattering phenomenon, which can be mitigated by the Boundary Layer Control (BLC) [4]. The other is how to choose parameters of the sliding mode control to minimize the error and control efforts. Up to now, try and error is the common method and it takes a long time to find a set of appropriate parameters for the sliding mode controller. Because the dynamics model of the formation flight system is highly nonlinear and the evaluation time is long, the conventional optimal method, such as the large-scale optimization given by Powell [1], does not work well. Therefore, the authors of this paper apply the genetic algorithm [2,3] to find the local and sub-optimal parameters for the sliding mode control.

The generalized dynamics model [6], which includes the relative position and attitude models, are adopted for the leader/follower satellites pair in the formation flight system. Boundary layer and sliding mode controllers are designed based on the genetic algorithm. Local minimums are found and demonstrate the high nonlinearity of the system.

08:50 AAS 03-649 A Guidance Algorithm for Formation Reconfiguration and Maintenance Based on the Perturbed Clohessy-Wiltshire Equations

T. A. Lovell - Air Force Research Laboratory; S. G. Tragesser - AFIT/ENY; M. V. Tollefson

In this paper a characterization of relative satellite motion is developed, beginning with the two-body Hill's equations and incorporating the effects of perturbing effects (primarily drag and J_2 forces). A multiple-impulse burn maneuver algorithm is developed that is based on a scheme presented in previous work, but that accounts for the perturbations. With the aid of numerical techniques, the best maneuvers are determined, in terms of fuel efficiency and practicality, for several test cases. Validation of the algorithm will involve a comparison of its performance to that of a scheme that accounts only for the two-body force.

09:10 AAS 03-650 Collision Avoidance During Rendezvous Via Relative Motion Approximation

T. A. Lovell, R. Howard - Air Force Research Laboratory,
K. Horneman, University of Missouri

In this paper a multiple-impulse burn maneuver algorithm based on the two-body Hill's equations that was presented in previous work, is further developed to allow reconfiguration and maintenance of non-planar formations. The potential advantages of varying the number of impulses, as well as the wait times between the impulses, are also explored. An investigation of the intermediate trajectories generated by the guidance policies will be studied to ensure that collisions are avoided. Examples applying the algorithms to various formation scenarios are presented, along with practical implications of each result.

09:30 AAS 03-651 Error Analysis of Satellite Formations In Near Circular Low Earth Orbits

K. T. Alfriend - Texas A&M University;
T. A. Lovell - Air Force Research Laboratory

This paper addresses the effect of random errors on the orbit maintenance of planar formations in near circular low Earth orbits. The formations considered are the leaderfollower (LF) and the centered in-plane ellipse (CIPE), which is the 2x1 ellipse with the center at the reference point of Chief satellite. The differential J_2 effects are not considered because their effect is caused primarily by an inclination change and secondarily by an eccentricity change. Since the formations are in the Chief orbit plane the former does not exist and the latter is proportional to $O(\square e^2)$, which is very small.

09:50 Break

10:20 AAS 03-652 Formation Maintenance for Low Earth Near-Circular Orbits

K. T. Alfriend, S.S. Vaddi - Texas A&M University;
T. A. Lovell - Air Force Research Laboratory

With the concept of satellites flying in precise formation becoming more of a reality numerous strategies, both continuous and impulsive, have been proposed for maintaining or controlling the formation. This paper addresses the use of tangential and out-of-plane impulsive control of a formation in near-circular low earth orbit. Near-circular does not mean assuming a circular orbit; it means that retaining terms of $O(e)$ is sufficient for the model.

10:40 AAS 03-653 Optimal Circular Formation Initialization With Collision Risk Management

A. Boutonnet, V. Martinot – Alcatel Space ; A. Baranov – KIA Systems ;
B. Escudier – SupAero ; J. Noailles – LIMA-N7

An optimal circular formation initialization solution is presented. To prevent collision with the rocket upper stage, an injection impulse is added and optimized. After the injection the optimal analytical two impulse solution is obtained by combining a geometrical approach with usual optimal control theory results. Then the collision risk is assessed and improved by tuning some parameters without increasing the ergol consumption. Afterwards dispersions are added to the impulses leading to unacceptable risk. They are corrected by introducing an adapted control law which also leads to a good final precision with a very low extra amount of fuel.

11:00 AAS 03-654 Minimum-Fuel/Minimum-Time Maneuvers of Formation Flying Satellites

G. Avanzini, D. Biamonti, E. Minisci - Polytechnic of Turin

A mixed approach for the optimization of the formation deployment maneuver for a set of formation flying satellites is proposed. The approach is based on an innovative evolutionary multi-objective optimization algorithm, based on the Parzen method for estimation of distributions. The algorithm demonstrated satisfactory performance in terms of solution accuracy, when compared to results obtained by “classical” Genetic Algorithms, on a simple test case, that requires the identification of a Hohmann transfer betweem LEO and GEO. In a more complex maneuver, the Pareto front in the maneuver time – fuel consumption plane is identified and the constraint enforcement is improved, refining the optimal solution by an SQP optimization algorithm.

11:20 AAS 03-655 Pulsed thrust method for hover formation flying

A. S. Hope, A. J. Trask - Naval Research Laboratory

A non-continuous thrust method for hover type formation flying has been developed. This method differs from a true hover which requires constant range and bearing from a reference vehicle. The new method uses a pulsed loop, or pogo, maneuver sequence that keeps the follower spacecraft within a defined box in a near hover situation. Equations are developed for the hover maintenance maneuvers. The constraints on the hover location, pulse interval, and maximum/minimum ranges are discussed.

11:40 AAS 03-656 Maintaining Periodical Relative Trajectories of Satellite Formation by Using Power-Limited Thrusters

D. Mishne – RAFAEL

This paper deals with the problem of maintaining periodical relative trajectories of a formation of LEO satellites. Using power-limited thrusters with variable thrust performs the control of the relative motion. Here we develop an optimal control law that drives one satellite from arbitrary initial conditions to desired drift-free relative trajectory with respect to another satellite, while minimizing the fuel consumption. For power-limited propulsion system, optimizing the fuel consumption requires a control law that minimizes the integral of the square of the thrust acceleration. The dynamics of the relative motion is modeled by modified Clohessy-Wiltshire linearized equations, developed recently, which include linearized, averaged effects of the earth oblateness (J_2) and the effect of the drag difference. The indirect optimization method is used to derive the optimal control law, which is expressed in a closed-form solution. Numerical results show that the thrust level and the fuel consumed are within the capabilities of modern Hall-type thrusters.

SESSION 21: FLIGHT EXPERIENCE

Chair : Jean de Lafontaine
Université de Sherbrooke

08:30 AAS 03-657 **Examination of NORAD TLE Accuracy Using the IRIDIUM Constellation**
W. H. Boyce III, S. J. Sponaugle, D. E. Gaylor - Boeing Satellite Operations & Ground Systems

Withdrawn

The accuracy of the General Perturbation NORAD TLE data has been the subject of much discussion and speculation. This paper examines the accuracy of the SGP4 element sets published by US Space Command (NORAD TLEs) using tracking data from live Iridium satellites. A [illegible]ge datab[illegible] of [illegible] [illegible]rom live Iridium sat[illegible] [illegible]nalysis. Iridium Orb[illegible] [illegible] tracking station conta[illegible] there is always plen[illegible] of a NORAD TLE. The Iridium esti[illegible] used as a basis for statistical calculations performed on [illegible] NORAD element sets, which are then used to assess the efficacy of using the NORAD element sets for collision avoidance.

08:50 AAS 03-658 **Validation of a GPS NAV Solution-Based Orbit Determination for Coriolis/Windsat**
J. A. DeYoung - Naval Research Laboratory

The Coriolis space vehicle flies Motorola Viceroy GPS receivers. GPS NAV solution data are included in both the X-band high-rate and S-band tactical telemetry streams. The use and validation of the GPS NAV-based orbit solutions for producing high-precision orbit determinations will be presented. Weighted least-squares fits using NRL's OCEAN5 software produce RMS residuals of from 2.0-m to 4.1-m. GPS NAV-based orbit solutions compared to SSN tracking data indicate good repeatability between the two measurement types.

09:10 AAS 03-659 **STARNAV I: Star Tracker Experiment on the Space Shuttle Mission STS-107**
M. A. Samaan, A. Katake, T. C. Pollock, J. L. Junkins - Texas A&M University

We report the results of a flight experiment aboard the ill-fated STS-107 Columbia Space Shuttle. Our results were telemetered during the first 10 days of the mission. The main purpose of the experiment was to test an advanced star pattern recognition algorithm. While the overall experiment was a success, we experienced un-anticipated difficulties. Due to the scattered light reflections off the SpaceHab roof, several image frames were not useable. Also, due to non-functioning thermo-electrical cooler, the background noise was higher than anticipated and varied during thermal cycling. However, these challenges were overcome and we report herein successive star identification and attitude determination results using a novel LISA (Lost-In-Space-Algorithm).

09:30 AAS 03-660 Design and On-Orbit Performance of the RHESSI Magnetic Attitude Control System

G. (Diane) Li, S. Fernandes - Spectrum Astro;
G. Creamer - U. S. Naval Research Laboratory

RHESSI spacecraft, launched on February 5, 2002, is a spin-stabilized, sun-pointing mission. It uses three magnetic torque rods to achieve attitude control, spin rate control and active nutation control as well as to acquire sun-pointing orientation from arbitrary initial attitude and typical launch vehicle tip-off rates. The simple low-cost, all-magnetic attitude control design requires no rate gyros, passive damping devices, magnetic field model, or ephemeris propagator. The ACS subsystem was also modified to fulfill a new mission of pointing RHESSI at other gamma ray and X-ray sources. This paper presents the attitude control system design and on-orbit results.

09:50 Break

10:20 AAS 03-661 Mars Odyssey Mapping Orbit Determination

J. Stauch, P. B. Esposito, R. A. Mase, P. Antreasian, S. Ardalan, D. Baird,
S. Demcak, E. Graat, D. Jefferson, G. G. Wawrzyniak - Jet Propulsion Laboratory

This paper will present the orbit determination (OD) strategy employed by the Odyssey navigation team, as well as the major navigation challenges and accomplishments. The most significant challenge in the OD process has been the trending and modeling of angular momentum desaturation (AMD) events, which significantly perturb the orbit. The predictable nature of the Odyssey momentum management strategy has allowed the navigation team to accurately model the trajectory perturbations due to the AMD thruster firings. In addition, the AMD perturbations have been used to control the desired orbit characteristics, mitigating the need for orbit maintenance maneuvers.

10:40 AAS 03-662 MUSES-C Launch and Early Orbit Operations Report

J. Kawaguchi, A. Fujiwara, T. Uesugi - The Institute of Space and Astronautical Science (ISAS)

The MUSES-C was launched in May of this year. The spacecraft is a kind of technology demonstrator with four key technologies including the use of ion engines in interplanetary cruise as a primary propulsion means. The first intermediate goal for the MUSES-C is at the Earth swingby that occurs in May of 2004, by which the spacecraft garners its orbit energy during the Electric Delta-V Earth Gravity Assist (EDVEGA) strategy. The paper presents a quick report on the initial operation of the ion engines aboard and also presents how much delta-V has been applied to the spacecraft as well as how the orbit determination under the low-thrust acceleration is performed.

11:00 AAS 03-663 "Nozomi" Consecutive Double Earth Swing-bys Flight To Mars - Guidance and Navigation Report

J. Kawaguchi, I. Nakatani, H. Hayakawa, M. Yoshikawa - The Institute of Space and Astronautical Science (ISAS)

"Nozomi" spacecraft that was launched in 1998 has continued its flight to the Mars. Last December and this June, it successfully performed the double consecutive Earth swingbys. This tactical orbit sequence alleviates the delta-V amount for the spacecraft to be captured around the Mars, and enables the scientific observation as planned originally. The paper reports how the guidance and navigation were carried out as for the swingbys. The paper especially refers to the delta-VLBI technique attempted and introduced. The contents of the paper are all based on the actual operation results.

SESSION 22: ANALYTICAL & NUMERICAL METHODS

Chair : Jon Sims
Cal-Tech Jet Propulsion Laboratory

08:30 AAS 03-664 Accuracy and Speed Effects of Variable Step Integration for Orbit Determination and Propagation

M. Berry - Virginia Polytechnic and State University and Naval Research Laboratory; L. Healy - Naval Research Laboratory

In this paper the fixed step Gauss-Jackson method is compared to two variable-step integrators. The first is the variable step, variable order Shampine-Gordon method. The second is s-integration, which may be considered an analytical step regulation. Orbit propagation and orbit determination are tested for speed and accuracy. Speed is assessed by computer processing time and accuracy is assessed by methods discussed by the authors in a previous work. Comparing these methods gives an indication of the types of orbits where variable step methods are advantageous.

08:50 AAS 03-665 A Precision Orbit Predictor Optimized for Complex Trajectory Operations

D. R. Adamo – United Space Alliance

Precise orbit prediction using Encke's method is proposed in the context of complex trajectory modeling. Complex trajectories are characterized by frequent spacecraft maneuvers and configuration changes. Capability to apply these changes accurately, reproducibly, and efficiently leads to selection of a self-starting numeric integration with physical time as the independent variable. Self-starting integration also supports a straightforward variable integration step size criterion further enhancing prediction speed while maintaining accuracy. Computation efficiencies associated with conic state vector prediction applied to Encke's method are presented. Finally, a detailed coding specification and easily implemented test cases invoking relevant perturbations are thoroughly documented.

09:10 AAS 03-666 On the Use of Differentials in Astrodynamics

D. G_ Hull - The University of Texas at Austin

Two important tools which are used extensively in astrodynamics are optimization theory and perturbation theory. For problems involving ordinary differential equations, each theory uses a nominal path and a perturbed path to derive the equations for the various order parts needed to develop the theory. Also, the usual procedure for obtaining these equations is the Taylor series expansion. It is shown that the process of making a Taylor series expansion is equivalent to the process of taking differentials, but with differentials the expansions can be made one order at a time. It is also shown that the various optimization theories (parameter optimization optimal control theory, …) are unified through the use of the differential, as are the various elements of perturbation theory.

09:30 AAS 03-667 Development of the Multipurpose Low Thrust Interplanetary Trajectory Calculation Code.

T. Sakai, J. R. Olds - Georgia Institute of Technology

A multipurpose low thrust interplanetary trajectory calculation code has been developed. This code integrates the equations of motion along the trajectory assuming that the spacecraft is subject to a single attracting body and a constant thrust during both heliocentric and planetocentric phases. To minimize the required propellant, the best thrust direction is obtained using calculus of variations. The output of the trajectory simulation is used as an input to mass estimation relationships that size the spacecraft. A VRML trajectory viewer helps to visualize how the spacecraft reaches its target.

SESSION 23: SPACE SURVEILLANCE, SPACE CATALOGUE

Chair : Al Cangahuala
Cal-Tech Jet Propulsion Laboratory

10:20 AAS 03-668 Improvements to Orbit Determination Algorithms for Automatic Catalog Maintenance

F. R. Hoots, G. S. Pierce - AT&T Government Solutions

The Naval Space Command maintains a catalog of over 10,000 satellites. Because of imperfections in the orbit models, each orbit must be periodically reinitialized to reconcile it with the actual satellite trajectory. It is desirable to have a process that operates without the need for human intervention. Such a process requires a robust set of algorithms for optimizing the update and rules to automatically judge the results. This paper describes the algorithms used for orbit maintenance and provides details of recent innovations that improve the robustness of the methods and decrease the need for human intervention. We discuss an improvement in the pseudo range computation for optical tracking sites and two different improvements in the along track orbit correction.

10:40 AAS 03-669 A New Sensor Resource Allocation Algorithm for the Space Surveillance Network in Support of the Special Perturbations Satellite Catalog

J. G. Miller - The MITRE Corporation

A new sensor resource allocation algorithm has been developed that optimally allocates tracks from the Space Surveillance Network (SSN) to maintain the special perturbations satellite catalog to meet the accuracy requirements in the Capstone Requirements Document (CRD) for Space Control. The required track density from the SSN to meet the accuracy requirements in the CRD increases with Energy Dissipation Rate (EDR), which is a measure of the amount of atmospheric drag a satellite experiences. The sensor resource allocation algorithm is based on marginal utility analysis. Each satellite has a concave utility function, which has decreasing marginal utility as more tracks from the SSN are allocated until the expected value of the number of acquired tracks reaches the required track density based on EDR. The allocation algorithm maximizes the sum of all the satellite utility functions.

11:00 AAS 03-670 More Chracterization of Space Surveillance Sensors Using Normal Places

J. H. Seago, M. A. Davis - Honeywell Technology Solutions;
W. R. Smith IV - Naval Research Laboratory

The US Space Commands rely on sample estimates of bias and standard deviation to monitor space surveillance network sensor performance over time. A discrepancy between forecast bias (based on historical data) and observed bias (based on current data) indicates that a sensor is no longer adequately calibrated. Under the auspices that a static bias model is the only practical method of assessment or correction, an objective level of discrepancy should be pre-defined. This paper proposes statistical methods to assess when a sensor requires re-calibration. For this application, the sensor errors are first reduced to normal places, since their stochastic behavior better accommodates forecast models for sensor bias and uncertainty.

11:20 AAS 03-671 Correcting Ionospheric Refraction in the Naval Space Surveillance System

J. H. Seago, M. A. Davis - Honeywell Technology Solutions;
W. R. Smith IV - Naval Research Laboratory

Ionospheric refraction is the dominate source of error in satellite observations from the Naval Space Surveillance System. Due to the very large number of observations per day needing real-time correction (170,000), a highly efficient refraction correction is required. A low-cost concept for real-time calibration of ionospheric refraction error is described in this paper. For this application, refraction is computed by a simplified ray bending formula using the electron content from an analytical ionospheric model. The precision of the simplified ray bending model is first assessed against numerical integration of the total path integral through the analytical ionosphere. The error uncertainty associated with using an analytical refraction model is also estimated.

11:40 AAS 03-672 The Examination of a Near Real Time Ionospheric Sensor and its Application to Naval Space Surveillance Fence Data

C. A. H. Walker, B. Davis - Northrop Grumman Mission Systems

The ionosphere has long posed a problem for low frequency signals, the accurate calculation of the delay it causes is important for high precision work using signals with frequencies below 1GHz. Due to the variability in the ionosphere accurate, real-time measurements are sought to replace the globally smoothed models currently used. As an alternative to ionospheric models this research project examined local ionospheric measurements from the Low Resolution Airglow and Aurora Spectrograph (LORAAS) sensor and applied them to data from the Navy Space Surveillance Fence. The specific focus was the use of these ionospheric measurements on a localized scale. Night side ionospheric measurements from the LORAAS instrument were compared to values obtained from the International Reference Ionosphere (IRI), TOPEX, and GPS Global Ionosphere Maps (GIM). Ionospheric corrections were then calculated for the data from the Navy Space Surveillance Fence using each method. The results of this study will be presented.

AUTHOR INDEX

Author	Session	Period
Cochran , J. E.	4	MonPM
Cochran, J. E.	5	MonPM
Codrescu, M.	16	WedPM
~~Colasurdo, G.~~	~~2~~	~~MonAM~~
~~Colasurdo, G.~~	~~10~~	~~TuePM~~
Congying, H.	8	TueAM
Conway , B. A.	17	WedPM
Coppi, V.	8	TueAM
Côté, J.	1	MonAM
Coverstone , V.	6	MonPM
Coverstone, V.	17	WedPM
Creamer , G.	21	ThuAM
Cupples , M.	6	MonPM
Cupples , M.	17	WedPM
Curti , F.	8	TueAM
D'Souza, C.	10	TuePM
Dabrowski , V. J.	14	WedAM
Dachwald , B.	10	TuePM
Davis, B.	23	ThuAM
Davis, M. A.	23	ThuAM
de Lafontaine , J.	1	MonAM
de Lafontaine , J.	15	WedAM
Demcak, S.	21	ThuAM
Desai , P. N.	19	WedPM
DeYoung , J. A.	21	ThuAM
Diaz , F. Chang-	10	TuePM
Duan, X.	12	TuePM
Dymond, K.F.	16	WedPM
Eke , F.O.	11	TuePM
Elipe , A.	9	TueAM
Ely , T. A.	4	MonPM
Emmert , J. T.	16	WedPM
Escudier , B.	20	ThuAM
Esposito, P. B.	21	ThuAM
Fernandes, S.	21	ThuAM
Fitz-Coy, N.	20	ThuAM
Folcik, Z. J.	4	MonPM

Author	Session	Period
Folta , D.	15	WedAM
Fonseca , I. M.	8	TueAM
Forbes, J. M.	16	WedPM
Fowler , W. T.	6	MonPM
Frakes, D.	12	TuePM
Francillout , L.	19	WedPM
Friedlander, A. L.	2	MonAM
Fujii , H. A.	5	MonPM
Fujiwara, A.	21	ThuAM
Fuller-Rowell , T.	16	WedPM
Fullmer , R. R.	15	WedAM
Gao, Y.	19	WedPM
~~Gaylor, D. E.~~	~~21~~	~~ThuAM~~
Gerencser, D.	18	WedPM
Gick , A.	7	TueAM
Goester, J.F.	19	WedPM
Goodson, T.	6	MonPM
Graat, E.	21	ThuAM
Green, S.	17	WedPM
Griffith , E.	13	WedAM
Grossbard , N.	16	WedPM
Guibout , V.	9	TueAM
Guibout, V.	10	TuePM
Hahn, Y.	6	MonPM
Haley , D. R.	14	WedAM
Hall , C.	1	MonAM
Hall, C.	5	MonPM
Hall, C.	8	TueAM
Hall, C.	14	WedAM
Hanson , J.	10	TuePM
Harman , R.	14	WedAM
Hartmann, J. W.	6	MonPM
Hartmann, J. W.	17	WedPM
Hashimoto, T.	11	TuePM
Haw , R.J.	19	WedPM
Hayakawa, H.	21	ThuAM
Healy , L.	1	MonAM
Healy, L.	16	WedPM

Author	Session	Period
Healy, L.	22	ThuAM
Henderlight, E.E.	16	WedPM
Henderson , T. A.	15	WedAM
Hoffman , J. H.	5	MonPM
Hoots , F. R.	23	ThuAM
Hope, A. S.	20	ThuAM
Horneman ,K.	20	ThuAM
Houghton, M. B.	11	TuePM
Howard, R.	20	ThuAM
Howell, K.C.	12	TuePM
Hsu, O. C.	11	TuePM
Hull , D. G_	22	ThuAM
Hurtado, J. E.	15	WedAM
Hyland, D.	6	MonPM
Iess, L.	5	MonPM
Ionasescu, R.	6	MonPM
Izutsu , H.	4	MonPM
Izzo , D.	7	TueAM
Jacobs, M.	2	MonAM
Jang , J.-W.	13	WedAM
Janin , G.	6	MonPM
Janssens , F.L.	9	TueAM
Javorsek , D.	3	MonAM
Jean , I.	15	WedAM
Jefferson, D.	21	ThuAM
Jesus , A. D. C.	3	MonAM
Jian, G.	8	TueAM
Jo , J. H.	4	MonPM
Jo , J. H.	5	MonPM
Johnson , M. C.	13	WedAM
Jokic , M. D.	5	MonPM
Jones, J.	6	MonPM
Jun, Z.	8	TueAM
Junkins, J. L.	14	WedAM
Junkins, J. L.	15	WedAM
Junkins, J. L.	21	ThuAM
Kabamba, P. T.	18	WedPM

Author	Session	Period
Kahler , S.	10	TuePM
Kashiwa , M.	12	TuePM
Katake, A.	21	ThuAM
Kawaguchi , J.	4	MonPM
Kawaguchi, J.	21	ThuAM
Kendra, M. J.	16	WedPM
Key, K	4	MonPM
Kim , I.	14	WedAM
Kim , M.	5	MonPM
Kim , Y.	14	WedAM
~~Kimball , J. D.~~	~~11~~	~~TuePM~~
Kluever , C. A.	19	WedPM
Knowles , S. H.	16	WedPM
Kojima, H.	11	TuePM
Kubitschek , D. G.	15	WedAM
Lachiver, G.	1	MonAM
Landau , D.	2	MonAM
Landi, A.	14	WedAM
Lara , M.	9	TueAM
Lean, J. L.	16	WedPM
Lee , D.-J.	4	MonPM
Lee , D.-W.	19	WedPM
Lemay, C.-E.	1	MonAM
LeVoci, P. A.	11	TuePM
~~Li , H.~~	~~12~~	~~TuePM~~
Li, G. (Diane)	21	ThuAM
Lightsey , G.	4	MonPM
Lo , M. W.	9	TueAM
Lo , M. W.	18	WedPM
Longman , R. W.	11	TuePM
Longo, F.	8	TueAM
Longuski , J. M.	2	MonAM
Longuski , J. M.	3	MonAM
Longuski , J. M.	5	MonPM
Lovell, T. A.	20	ThuAM
~~Lovellette, M. N.~~	~~15~~	~~WedAM~~
Lu, P.	10	TuePM
Lyne , J. E.	19	WedPM
Lyon , R.	4	MonPM

Author	Session	Period
Lyons , D. T.	19	WedPM
Mackison , D. L.	1	MonAM
Maghami, P. G.	11	TuePM
Marchand , B.G.	12	TuePM
Marcos , F. A.	16	WedPM
Markley , F. L.	11	TuePM
Marr , G. C.	4	MonPM
Martel , F.	11	TuePM
Martinot , V.	20	ThuAM
Mase, R. A.	21	ThuAM
Mason , P. A. C.	20	ThuAM
Matunaga, S.	12	TuePM
Mazzoleni , A. P.	5	MonPM
McAdams , J. V.	6	MonPM
McConaghy, T. T.	2	MonAM
McCoy , R.P.	16	WedPM
McCoy , S.M.	16	WedPM
McDaniel , P. J.	18	WedPM
Melton, R. G.	1	MonAM
Mendelsohn, C.	15	WedAM
Miele , A.	10	TuePM
Millard , L.	6	MonPM
Miller , J. K.	15	WedAM
Miller, J. G.	23	ThuAM
Minisci, E.	20	ThuAM
Minter, C.	16	WedPM
Mishne , D.	20	ThuAM
Misra , A.	5	MonPM
Moffitt , B. A.	19	WedPM
Monda , E.	4	MonPM
Moreno-Rivera, C.	19	WedPM
Mortari, D.	14	WedAM
Mosher , T. J.	19	WedPM
Nakatani, I.	21	ThuAM
Nazarenko, A. I.	16	WedPM
Nerem , R. S.	16	WedPM
Neveu, D.	1	MonAM
Nicholas , A.C.	16	WedPM

Author	Session	Period
Noailles , J.	20	ThuAM
Nock , K. T.	2	MonAM
Ocampo, C.	2	MonAM
Ocampo, C.	10	TuePM
Ocampo, C.	17	WedPM
Oh, S. J.	11	TuePM
Olds, J. R.	22	ThuAM
Oshman , Y.	14	WedAM
Ott, C.	19	WedPM
Owen , W.	6	MonPM
Pack, R.	15	WedAM
Parisse, M.	8	TueAM
Park, C.	10	TuePM
Patera , R. P.	3	MonAM
Patterson , P.	15	WedAM
Pederson , A.	1	MonAM
Pelaez , J.	5	MonPM
Pernicka , H. J.	18	WedPM
Peterson , G. E.	7	TueAM
Petropoulos , A. E.	17	WedPM
Phelps, E.	7	TueAM
Phillips, R. F.	13	WedAM
Picone, J. M.	16	WedPM
Pierce, G. S.	23	ThuAM
Pittelkau, M. E.	8	TueAM
Pojman, J.	6	MonPM
Pollock, T. C.	14	WedAM
Pollock, T. C.	15	WedAM
Pollock, T. C.	21	ThuAM
Proulx , R. J.	10	TuePM
Proulx , R. J.	16	WedPM
Radice, G.	15	WedAM
Ramsey, P.	19	WedPM
Ranieri , C.	10	TuePM
Rao , V. G.	18	WedPM
Rauwolf , G. A.	2	MonAM
~~Ray , P. S.~~	~~15~~	~~WedAM~~

Author	Session	Period	Author	Session	Period
Rodden, J. J.	18	WedPM	Theisinger, J. E.	15	WedAM
Roth , D.	6	MonPM	Thienel, J.	14	WedAM
Roundhill, I.	6	MonPM	Thonnard , S.	16	WedPM
Russell , R. P.	2	MonAM	Tobiska, W. K.	16	WedPM
			Toews , C.	7	TueAM
Sakai , T.	22	ThuAM	Tollefson , M. V.	20	ThuAM
Salcedo, C.	12	TuePM	Tragesser , S. G.	1	MonAM
Samaan , M. A.	14	WedAM	Tragesser, S. G.	20	ThuAM
Samaan, M. A.	21	ThuAM	Trask, A. J.	20	ThuAM
Santos , F. B. M.	3	MonAM	Trivailo , P.	5	MonPM
Santos, S.	6	MonPM	Tse, M.	18	WedPM
Scheeres , D.J.	3	MonAM	Tsiotras , P.	9	TueAM
Scheeres , D.J.	9	TueAM	Turner , A. J.	1	MonAM
Scheeres , D.J.	10	TuePM	Turner , A. E.	18	WedPM
Schleicher , A.	4	MonPM			
Schoenenberger, M.	19	WedPM	Uesugi, T.	21	ThuAM
Schwartz , J.	14	WedAM			
Seago , J. H.	23	ThuAM	Vadali, S. R.	12	TuePM
Senet , J.	17	WedPM	Vaddi , S.S.	12	TuePM
Sharer , P.	7	TueAM	Vaddi, S. S.	20	ThuAM
~~Sheikh , S. I.~~	~~15~~	~~WedAM~~	Vallado , D. A.	4	MonPM
Shen , H.	9	TueAM	Villac , B.F.	3	MonAM
Sinclair, A. J.	15	WedAM	Vincent , M. A.	12	TuePM
Singhose, W.	12	TuePM			
Skelton, C. E.	8	TueAM	Wagner, S.	6	MonPM
Smith IV , W. R.	23	ThuAM	Walker , C. A. H.	23	ThuAM
Somenzi , L.	5	MonPM	Wang, T.	10	TuePM
Sookgaew, J.	11	TuePM	Wawrzyniak, G. G.	21	ThuAM
Spencer , D. B.	1	MonAM	Weber, B.	19	WedPM
~~Sponaugle, S. J.~~	~~21~~	~~ThuAM~~	Whiffen , G. J.	6	MonPM
Stanton, S.	10	TuePM	Williams , P.	5	MonPM
Stauch, J.	21	ThuAM	Williams, P. N.	10	TuePM
Strange , N.	6	MonPM	~~Williams, Trevor~~	~~12~~	~~TuePM~~
Strikwerda, T. E.	14	WedAM	Wise, J. O.	16	WedPM
Subramaniam , M.	13	WedAM	~~Wolff , M. T.~~	~~15~~	~~WedAM~~
Sutton, E.	16	WedPM	Wong, M.	6	MonPM
			Woo , B.	6	MonPM
Tanygin , S.	11	TuePM	Woo , M.-Y. P.	5	MonPM
Tapley , B. D.	16	WedPM	~~Wood, K. S.~~	~~15~~	~~WedAM~~
Theil , S.	4	MonPM	Woodburn , J.	1	MonAM

Author	Session	Period
Woodburn, J.	3	MonAM
Wright , J. R.	3	MonAM
Xu , Y. (Gregory)	20	ThuAM
Yamakawa , H.	3	MonAM
Yan, H.	9	TueAM
Yang, L.	13	WedAM
Yoshikawa, M.	21	ThuAM
Yurasov, V. S.	16	WedPM
Zheng, Y.	8	TueAM
Zimmer, S.	10	TuePM

NOTES

RECORD OF MEETING EXPENSES

2003 AAS/AIAA Astrodynamics Specialist Conference
Big Sky Resort
Big Sky, Montana
August 3-7, 2003

Name: ______________________ Organization: ______________________

Registration Fee:
- AAS or AIAA Member $210 __________________
- Non-Member @ $295 __________________
- Student @ $25 __________________

Conference Proceedings @ $190 __________________
Technical Paper Sales @ $1.00 per paper __________________

Rainbow Ranch Lodge Barbecue @
- $30 adult __________________
- $15 child under 12 __________________
- Free for children under 3 __________________

TOTAL: __________________

Technical Paper Purchases

# of Papers	Cost	Date

Big Sky, MT
Inside Back
Cover

Program at a Glance

	Sunday, August 3	Monday, August 4	Tuesday, August 5	Wednesday, August 6	Thursday, August 7
Registration	4:00 pm - 8:00 pm	7:00 am - 4:00 pm	8:00 am - 4:00 pm	8:00 am - 4:00 pm	8:00 am - 10:00 am
Speaker's Breakfast		7:00 am - 8:00 am	7:30 am - 8:30 am	7:30 am - 8:30 am	7:30 am - 8:30 am
Morning Sessions 8:30 am -11:40 am		Innovations in Astronautics Education Dunraven/Obsidian	Orbital Debris, Collision Probability Dunraven/Obsidian	Attitude Determination, System Identification Dunraven/Obsidian	Flight Experience Dunraven/Obsidian
		Mission & Trajectory Design-I Gallatin	Attitude Dynamics & Control – I Gallatin	International Space Station Gallatin	Formation Flight - II Gallatin
		Orbit Control, Orbital Transfers-I Lamar/Gibbon	Orbital Dynamics Lamar/Gibbon	Autonomous GNC Systems Lamar/Gibbon	Space Surveillance, Space Catalogue Lamar/Gibbon
					Analytical & Numerical Methods Dunraven/Obsidian
Committee Luncheons		AIAA Astrodynamics TC 11:30 am - 1:30 pm Huntley N. Dining Room	AAS Astrodynamics TC 11:30 am - 1:30 pm Huntley N. Dining Room	AIAA Astrodynamics Standards 11:00 am - 2:00 pm Huntley N. Dining Room	
Afternoon Sessions 1:30 pm - 5:20 pm		Orbit Determination, Navigation Dunraven/Obsidian	Optimal Trajectory Design & Optimal Control Dunraven/Obsidian	Neutral Density and Satellite Drag Dunraven/Obsidian	
		Tethers Lamar/Gibbon	Attitude Dynamics & Control - II Lamar/Gibbon	Aerocapture, Atmospheric Entry Lamar/Gibbon	
		Mission & Trajectory Design – II Gallatin	Formation Flight-I Gallatin	Orbit Control, Orbital Transfers - II Gallatin	
				Constellation Design & Coverage Analysis Gallatin	
Evening Events	Early-Bird Reception 6:00 pm - 9:00 pm Peaks Lounge	BBQ at the Rainbow Ranch Lodge 6:30 pm - 11:00 pm Off-Site	Modi Plenary Session 5:30 pm - 6:30 pm Gallatin	Happy Hour Cocktail Reception 6:00 pm - 8:00 pm Peaks Lounge	
	Star Party 9:00 pm - 11:00 pm Behind the Huntley		Star Party 9:00 pm - 11:00 pm Behind the Huntley		

Morning Break: 9:50 am - 10:20 am
Afternoon Break: 2:50 pm - 3:20 pm
Paper Sales: Lake/Canyon Room

Big Sky, MT
Outside Back
Cover

Big Sky Personal AAS/AIAA Conference Planner

Sunday

Start Time	Activity	
700		
730		
800		
830		
850		
910		
930		
950		
1020		
1040		
1100		
1120		
1130		
1200		
1230		
100		
130		
150		
210		
230		
250		
310		
330		
350		
400	**Early**	
430	**Registration**	
500	**(Firehole**	
530	**Lounge)**	
600	**Early**	
630	**Registration**	**Early-Bird**
700	**(Peaks**	**Cocktail**
730	**Lounge)**	**Party**
800		**(Peaks)**
830		
900 930 1000 1030	**Star Party** (Behind the Huntley Lodge)	

Monday

Start Time		Session	Room	Paper/Activity	
700			N. Dining	**Speaker's**	
730			Huntley	**Briefing**	
800			Gallatin	Conference Welcome	
830					
850					
910					
930					
950			Atrium	**Coffee Break**	
1020					
1040					
1100					
1120					
1130				**AIAA**	
1200			N. Dining	**Astrodynamics**	Lunch
1230			Huntley	**TC**	(on your
100				**Meeting***	own)
130					
150					
210					
230					
250			Atrium	**Coffee Break**	
320					
340					
400					
420					
440					
500					
530					
600					
630				**Special**	
700			Off-Site	**Dinner**	
730				**and**	
800				**Reception**	
830					
900 930 1000 1030				**Rainbow Ranch Lodge**	

Tuesday

Start Time		Session	Room	Paper/Activity	
700					
730			N. Dining	**Speaker's**	
800			Huntley	**Briefing**	
830					
850					
910					
930					
950			Atrium	**Coffee Break**	
1020					
1040					
1100					
1120					
1130				**AAS**	
1200			N. Dining	**Spaceflight**	Lunch
1230			Huntley	**Mechanics**	(on your
100				**TC Mtg***	own)
130					
150					
210					
230					
250			Atrium	**Coffee Break**	
320					
340					
400					
420					
440					
500					
530			Gallatin	**Modi Plenary**	
600				**Session**	
630					
700					
730					
800					
830					
900 930 1000 1030				**Star Party** (Behind the Huntley Lodge)	

Wednesday

Start Time		Session	Room	Activity/Paper	
700					
730			N. Dining	**Speaker's**	
800			Huntley	**Briefing**	
830					
850					
910					
930					
950			Atrium	**Coffee Break**	
1020					
1040					
1100					
1120					
1130				**AIAA**	
1200			N. Dining	**Astrodynamics**	Lunch
1230			Huntley	**Standards**	(on your
100				**Committee***	own)
130					
150					
210					
230					
250			Atrium	**Coffee Break**	
320					
340					
400					
420					
440					
500					
530					
600				**Cocktail**	
630				**Reception**	
700			Peaks	**and**	
730				**Awards**	
800					
830					
900 930 1000 1030				**Star Party Rain-Date**	

Thursday

Start Time		Session	Room	Activity/Paper
700				
730			N. Dining	**Speaker's**
800			Huntley	**Briefing**
830				
850				
910				
930				
950			Atrium	**Coffee Break**
1020				
1040				
1100				
1120				
1140				
1200	Conference Ends			
1230				
100				

* Committee members only