Proceedings of the First Annual NRO-OSL/GSFC-ATS Rideshare Conference

William Cutlip, Ed.

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 1999
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Proceedings of the

1st Annual
NRO-OSL/GSFC-ATS
Rideshare Conference

April 15-16, 1999
FIRST ANNUAL

GODDARD SPACE FLIGHT CENTER – ACCESS TO SPACE GROUP
NATIONAL RECONNAISSANCE OFFICE – OFFICE OF SPACE LAUNCH

RIDESHARE CONFERENCE

Mr. William Cutlip and Mr. Jim Liller
Co-Chairmen

LITTON/TASC FACILITY
DULLES, VIRGINIA

April 15-16, 1999
FIRST ANNUAL GSFC-ATS/NRO-OSL
RIDESHARE CONFERENCE

15 Apr 99

8:00  Security           Chip Harbaugh/TASC
8:10  Opening Remarks    Lt Col Arey/NRO/OSL/APD
8:20  Administrative      Jim Liller/NRO
8:30  Agenda              Jim Liller/NRO
8:35  RideShare Catalog  Jim Liller/NRO
8:50  Access To Space Program Bill Cutlip/GSFC/ATS
9:05  Rapid S/C Development Office (QuickRide) Jim Adams/GSFC
9:25  Spartan Project Office Dave Shrewsberry/GSFC
10:10 Break               Chris Dunker/GSFC
10:20 Shuttle Small Payloads Project Pete Thomas/AFRL
10:40 MightSat Program    Scott Yeakel/Spectrum Astro
11:00 Spectrum Astro Buses Phil Smith/ISS
11:20 Lunch               Trip Carter/LMA
12:30 Integrated Space Systems Buses Regan Howard/Orbital
12:50 Athena              Terry Schrepel/Ball Aerospace
1:00  Orbital Buses       Ed McNamara/LMMS
1:20  Ball Aerospace Buses Jim Ritter/NRL
1:40  Lockheed Martin Buses Mike Cully/Swales
2:00  Break               Donald Marshall/TRW
2:10  Orbiting Tech Testbed Initiative Jason O'Neil/Final Analysis
2:20  Swales Bus           Paul Regeon/ONR
2:35  TRW Buses            Bob Twiggs/Stanford University
2:55  FAISAT™              Dennis Smith/MSFC
3:15  GEO Bus              Therese Thrift/USA
3:30  Stanford MicroSat    Jim Liller/NRO
3:45  Space Transportation Program Jack Sevier/USRA
4:05  United Space Alliance Truss Bardos/SpaceHab

16 Apr

8:00  Agenda               Jim Liller/NRO
8:05  Universities Space Research Assoc Jack Sevier/USRA
8:20  SpaceHab             Truss Bardos/SpaceHab
8:40  NanoSat Deployment Concepts Steve Huybrechts/AFRL
8:55  SERB/STP              Maj Ward/AQSL
9:15  EELV Secondary P/L Adapter Capt. Scott Haskett/SMC-TELO
10:00 Break                Joe Young/Swales
10:15 PuckSat               Lt Col Verderame/AFRL
10:30 Space Maneuver Vehicle Frank Krens/Coleman Aerospace
11:15 Coleman Aerospace Vehicle Systems Maj Buckley/SMC-TEB
11:30 Lunch                 Lt. Col Hilland/AFRL
12:30 Orbital Sub-Orbital Program Albert Sierra/NASA HQ
1:00  Sat Threat Warning/Attack Rpt Prog Ed Morris/Orbital
1:15  NASA ELV Program/Policy Bill Files/Boeing
1:30  Pegasus/Taurus        Mike Ragole/Lockheed Martin
1:50  Boeing Delta II & EELV All
2:10  Lockheed Martin EELV
2:30  Secondary Payload Broker Discussion
The ATS Group will support the Goddard Space Flight Center's science and technology community by facilitating frequent, affordable opportunities for access to space and shall be advocates of change to reduce the cost of access. The ATS Group will utilize its experience and knowledge to provide comprehensive customer support throughout the entire mission cycle. This support will be thorough, innovative, and timely to ensure long-term customer satisfaction.
Goddard Space Flight Center

- Enable discovery through leadership in Earth and space science
- Serve the scientific community, inspire the Nation, foster education, and stimulate economic growth
- Partner with others to achieve NASA's goals
- Be innovative in all that we do
Phases

- The ATS Agent is responsible for the successful provision of
  - Timely, comprehensive information regarding access opportunities
  - Technical details specific to each opportunity
  - Related cost information
  - Supplier specified points-of-contact
Phases

- Will be the project's single point of contact for access-related information and questions
- Will propose alternate methods, when appropriate, in order to satisfy the customer's needs and requirements
- Will continuously evaluate the access mode work performed and procedures used for improvement in efficiency and lowering costs. Will work to prevent requirements to change in scope to the extent that costs and schedules are effected
Partnerships

NASA Centers
Partnerships

GSFC Customers
The ATS Group will support the Goddard Space Flight Center's science and technology community by facilitating frequent, affordable opportunities for access to space and shall be advocates of change to reduce the cost of access. The ATS Group will utilize its experience and knowledge to provide comprehensive customer support throughout the entire mission cycle. This support will be thorough, innovative, and timely to ensure long term customer satisfaction.

Developing a Mission?
Looking for a Ride?

How far do you want to go today?
http://accesstospace.gsfc.nasa.gov

Looking for a Ride?

How far do you want to go today?
Distributed Knowledge Base

ATS Web Page

Access To Space Opportunities

Reduced Access Cost

Access Mode Information

NRO

MSFC

KSC

Boeing

LMA

Orbital
Add A Mission

Mission Name:
Mission Status: Manifested
Mission Budget: None
Mission URL Link:
Launch Date:
Launch Window Duration (min):
Launch Window Open/Close: TBD
Seasonal Window: TBD
Apogee (km):
Perigee (km):
Inclination (deg):
Arg Of Perigee (deg):
C3 (km2/s2):
Ascending Node (deg):
or MLT:
Primary Payload Mass (kg):
Spacecraft Length (m):
Spacecraft Diameter (m):
The ATS Web Page Provides “Tool Boxes” for:

- Access Opportunities
- Performance
- Interfaces
- Volume
- Environments
- “Wish List” Entry
- Educational Outreach
Customer Satisfaction
Agreements

ATS Group

Customers

Suppliers
Advocates of Change
For Further Information, Please Contact:

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    FAX: (301) 286-1696-0232

• Project Formulation Office
  - Tom Taylor
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    FAX: (301) 286-0232
Access To Space Group

---ATS/NRO Rideshare Conference---

William E. Cutlip
Group Leader, Access To Space Group
Where's ATS?
Here's ATS

Thomas Taylor, Chief
Sandra Cauffman, Deputy Chief
Patrice Cogswell, Secretary

Access to Space Agents (ATSA)
- Carrie, Bill, ATS Group Lead
- Buchanan, Robert
- Goos, Francis M.
- Leon, John
- Vacant
- Woodall, Clyde

Business Management Office (FPO)
- Sass, Dino
- Resource Analyst
- Vacant
- Marecek, Laura
- Business Support Specialist

Technical Support
- Azzolini, John
- Advanced Project Technologist (SED)
- Badri Younce
- Spectrum Manager (FPO)

Carrier Managers (HST)
- Hubbard, Mark
- Krupacs, Eric
"The ATS Group will support the Goddard Space Flight Center's science and technology community by facilitating frequent, affordable opportunities for access to space and shall be advocates of change to reduce the cost of access. The ATS Group will utilize its experience and knowledge to provide comprehensive customer support throughout the entire mission cycle. This support will be thorough, innovative, and timely to ensure long term customer satisfaction."

(ATS Strategic Plan Signed By GSFC Center Director 10/22/98)
Charter

• Provide frequent, affordable opportunities for GSFC customers to make new measurements across a wide range of instrument platforms

• Maintain models/database of world-wide ATS performance/interface capabilities, access to space opportunities, and customers’ needs

• Facilitate the reduction of ATS cost over the full mission life cycle

• Participate in entire mission life cycle
Access To Space Agents

Process Flow

Pre-Formulation  Formulation  Approval  Implementation

Customers  Suppliers
Old Versus The New

NEW PROCESS

<table>
<thead>
<tr>
<th>Pre-Formulation</th>
<th>Formulation</th>
<th>Approval</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabling Activities</td>
<td>Definitize Project</td>
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<td></td>
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</table>

TRADITIONAL PHASES

<table>
<thead>
<tr>
<th>Pre-A Advanced Studies</th>
<th>A Conceptual Design Studies</th>
<th>B Concept Definition/ Initial Baseline</th>
<th>C Design Development</th>
<th>D Fabrication I&amp;T</th>
<th>E Pre-Operations</th>
<th>F Operations/ Disposal</th>
</tr>
</thead>
</table>

Launch
Project Formulation

Enabling Activities

- Requirements
- Mission Concepts
- Technology
- Programmatic
- Advocacy
- Partnerships
- Access To Space

Definitize Project

Project Approval Package

Implementation
Project Support

• Pre-Formulation/Formulation Process
  - “The Access To Space Agent (ATSA) supports all Access To Space-related technical and programmatic processes in support of GSFC’s development of feasible mission concepts, Project Formulation and Implementation activities.”
  - The ATSA is responsible for the following:
    • Provision of timely, comprehensive information regarding access opportunities, technical details specific to each opportunity, related cost information, and customer satisfaction with the products delivered.
    • Development of Web-based tools and databases to support assessment of all access modes and related technical and programmatic aspects.
    • Formulation and implementation of a standardized assessment package.
    • Formulation and implementation of MOAs with other Centers to facilitate.
Web-based Tools and Database: Mission Statement

"Develop and maintain a web site that provides both the information and the tools to assist mission planners in selecting and planning their ride to space. This includes the evaluation of single payloads vs. ride-sharing to reduce the cost of access to space."
Web Site Contents

- Database of information on foreign and domestic launch vehicles
  - The equivalent of an abbreviated on-line user's guides in a single location with the ability to view side-by-side comparisons of data in like formats
- Database of all missions planning to fly
  - Future concepts, Proposed missions, Manifested
- Interactive tools to quickly and easily scan through the data to search for candidate vehicles and ride-sharing/co-manifest opportunities
- Ability for registered users to add missions and share ideas to foster partnerships
Implementation Plan

- Design and develop the core system
- Populate the databases with current information
- Place Release 1 online and publicize the site
- Receive customer feedback and enhancement suggestions
- Continue to expand functionality of the site
- Work with other organizations, both commercial and government, to continually evolve to meet all user's needs
Where We Are

- **Design and develop the core system**
  - Initial release is in testing phase

- **Populate the databases with current information**
  - **LVs:** Have been working with industry suppliers since last Fall to supply data in a standard/consistent format
  - **Missions:** Already contains mission information from NASA's database and other mission information from NRO

- **Place Release 1 online and publicize the site**

- **Release 1 will go online in May**

- **We are demonstrating the site at this conference**
  - Receive customer feedback and enhancement suggestions
• All users can browse the site by entering as a ‘guest’
• Registered users gain additional benefits such as:
  - Stored user sessions
  - Printable “walk-away packets”
  - Access tools to enter/edit mission data into the mission database
Mission Data Input

- Registered users enter mission data through a series of data input panels
- Data topics include:
  - Orbit Parameters
  - Secondary/Co-manifest
  - Spacecraft Characteristics
  - Launch Vehicle
  - Other Mission Notes
  - Contact Information
Mission Design Home Page

- When using the mission design site, the user has three options from the main page:
  1. Query Mission Database
  2. Search for candidate rides
  3. Investigate Launch Vehicles in detail
Option 1: Query Mission Database

- Input search data
- Click "go"
- Results returned here
From the sort results, you can view the mission details

- Orbit Parameters
- Secondary/Co-manifest
- Spacecraft Characteristics
- Launch Vehicle
- Other Mission Notes
- Contact Information
Option 2: General Search Toolbox

- Enter target orbit and payload mass
- Query returns candidate launch vehicles and potential ride-share matches
Candidate Launch Vehicles and Ride-Shares

• Launch Vehicles
  – Based on the payload mass and orbit requested, the vehicle performance curves are scanned and the vehicle returned if the orbit can be achieved
  – The user can then click on the selections to research the candidate vehicles in detail

• Ride-Shares
  – Additionally, the mission database is scanned to identify ride-share candidates based on the payload mass and orbit proximity
  – The results are separated by mission status
  – You may click on the mission name to view the mission details
## General Search Toolbox Results

Search results for Altitude of 4500(km), Inclination of sun-synchronous(deg).

<table>
<thead>
<tr>
<th>Access Mode</th>
<th>Max Payload (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta IV(920-9.2)</td>
<td>3560</td>
</tr>
<tr>
<td>Delta IV(920-10)</td>
<td>3426</td>
</tr>
<tr>
<td>Proton(Personnel)</td>
<td>277</td>
</tr>
</tbody>
</table>

### Select Results for Shared Ride Opportunities
Select a mission name for detailed information.

#### Manifested

<table>
<thead>
<tr>
<th>Mission Name</th>
<th>Launch Date</th>
<th>Secondary Status</th>
<th>Payload Mass (kg)</th>
<th>Allocated Mass (kg)</th>
<th>Allocated Volume (Cylindrical) (m) x length (m)</th>
<th>Secondary Application Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBSAT-4</td>
<td>09/01/2000</td>
<td>Secondary+co-</td>
<td>300</td>
<td>300</td>
<td>1.1 x 1.33</td>
<td>07/01/1999</td>
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<tr>
<td></td>
<td></td>
<td>manifest opportunity available</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>LM-032</td>
<td>09/01/2000</td>
<td>Secondary+co-</td>
<td>0</td>
<td>150</td>
<td>0.66 x 0</td>
<td>07/01/1999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>manifest opportunity available</td>
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</table>

#### Proposed Missions

<table>
<thead>
<tr>
<th>Mission Name</th>
<th>Launch Date</th>
<th>Secondary Status</th>
<th>Payload Mass (kg)</th>
<th>Allocated Mass (kg)</th>
<th>Allocated Volume (Cylindrical) (m) x length (m)</th>
<th>Secondary Application Deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAFIRE-8</td>
<td></td>
<td>Locked for a ride</td>
<td>200</td>
<td>0</td>
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</tbody>
</table>

#### Future Concepts

<table>
<thead>
<tr>
<th>Allocated Volume</th>
<th>Secondary</th>
</tr>
</thead>
</table>
Option 3: Launch Vehicle Toolboxes

- The launch vehicle toolboxes provide the user with a wealth of data on each vehicle in areas such as:
  - General Information/Overview
  - Performance
  - Available Volume
  - Environments
  - Payload Interface
  - Launch Sites
Option 3: Launch Vehicle Toolboxes (Continued)

- On the first page, you select the class and/or configuration you wish to research.
Vehicle Class Overview

- For vehicle class information, click on the menu selections on the left menu
  - Vehicle History and Description
  - Configurations Available
  - Naming Conventions
  - Educational Outreach
Vehicle Configuration Details

- To view configuration information, use both the top and side menus.
- The top menu allows you to select the toolbox (major category).
- The side menu presents the topics contained in each toolbox.
Once you have completed your session, you may go to the "Print Options" selection tool. This tool allows you to select items from the toolboxes and searches that you want to print, alleviating the need to print individual pages.

Access To Space
Interactive Web Site

Vehicle Data Packet for user
Dr. Robert H. Goddard, XII
Launch Vehicle Information for the
Pegasus XL

January 20, 1999
What We Have Accomplished

- We have developed one single location for mission planners to seamlessly investigate the three means to reach space:
  - Ride share
  - Co-manifest
  - Single payload
What We Need

• Full involvement from the Access Mode Supplier community

  – The basic tools are in place, but we need the vehicle data to make the site a true “portal” to the access to space world

• Full involvement from everyone who has a ride or is looking for a ride
Planned Enhancements

- Add a user-registration system
  - Stored user sessions
  - Printable ‘walk-away’ packets
  - User-tools to add missions to the database
- Comparison and payload visualization
- Special requests section
- Expand ride-sharing for spacecraft bus availability
- Expand to other access modes (Shuttle, balloons, sub-orbital)
### Milestone Schedule

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Q2 '99</th>
<th>Q3 '99</th>
<th>Q4 '99</th>
<th>Q1 '00</th>
<th>Q2 '00</th>
<th>Q3 '00</th>
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<td>Release 1 On Line</td>
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<td>User Registration System</td>
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<td>Special Requests Section</td>
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<tr>
<td>Comparison and Payload Visualization</td>
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<tr>
<td>Spacecraft Bus Ride-Sharing</td>
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<td>Additional Access Modes</td>
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<tr>
<td>(Shuttle, balloons, Sub-orbital)</td>
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</tbody>
</table>
Formulation Assessments (Web Assisted)

- Address All Access Modes
  - ELVs, RLVs, Balloons, Shuttle, Spacecraft, Shared Rides
  - U.S. and Foreign, Government and Commercial
- Phase I/II Process
  - Phase I identifies
    - Project Specifics
    - Potential Access Modes
  - Technical & Programmatic specifics for each
  - First Cut Trade Space
  - Phase II fine tunes, based on Customer input on Phase I
Potential Access Modes
(Summary Sheet Example)

• Shuttle
  ➔ Inclination and "Shuttle-compatible" mods are show-stoppers
  • Time for plane change excessive
• High Altitude Balloons
  ➔ Altitude and time-on-orbit requirements are show-stoppers
• Instrument Only Ride
  ➔ Potential Access Mode
• Expendable/Reusable Launch Vehicles
  ➔ Potential Access Mode
Potential Launch Vehicles
(Summary Sheet Example – all prices are estimates from public sources)

- Expendable Launch Vehicles
  - Atlas IIA  SLC-3 at VAFB  Massive Performance Margin  $85M
  - Titan II SLV  SLC-4W at VAFB  Elliptical Orbit  $32M
  - Athena II  Kodiak Island (?)  Approx. 325kg of Margin  $28M
  - Delta II  SLC-2 at VAFB  Massive Performance Margin  $45M
  - Kosmos  Baikonur & Plesetsk  1,400kg to 400km  $14M
    - Launched FAISAT-2V s/c 9/23/97 out of Plesetsk, 825kg s/c
  - Proton Block DM  Baikonur  Massive Performance Margin  $30M
    - Used for Iridium missions, also Asiasat 3, Inmarsat 3 F2, Telstar 5
  - Rokot  Baikonur  1,850kg to 300km  $3M
  - Soyuz  Baikonur & Plesetsk  Massive Performance Margin  $36M
  - Zenit  Sea Launch & Baikonur  Massive Performance Margin  $65M
  - Tsyklon 3  Plesetsk  Massive Performance Margin  $11M
  - Ariane 44L  Kourou  Massive Performance Margin  $82M
  - Long March  Xichang  Massive Performance Margin  $10-25M

Note: Acquisition of foreign launch services requires Presidential waiver of National Space Policy.
Potential Launch Vehicles
(Summary Sheet Example – all prices are estimates from public sources)

• Reusable/New Expendable Launch Vehicles
  - Kistler K-1 Woomera Rocket Range ~1,770kg to 600km, 94 deg $17M
    • First launch end of CY98/beginning of CY99
    • Contract with Space Systems/Loral for 10 launches - first launch 4Q CY99
    • ~$4,800/lb.

    • First launch scheduled for late CY99

  - Pioneer RocketPlane Take-off VAFB Requires Upper Stage on s/c $45M

  - Kelly Space Astroliner Take off EdwAFB Massive Perf. Margin (?) $9M (?)
    • Scheduled for start of commercial operations by mid-2001

    • Flight tests scheduled for CY99, commercial service mid CY00
    • $1,000/lb.
Project Support (Implementation)

- Implementation Process

  - "The ATSA, to the extent requested by the GSFC Customer, will continue to support the Customer throughout the Implementation phase as the Customer’s representative with the implementing access mode organization."

- Project’s single point of contact for access-related info and questions.

- Allows Customer to concentrate on development and delivery of the payload (spacecraft and/or instrument).
Change Advocacy

Example: Small orbit-raising propulsion system
Current ATS Workload

- Currently supporting
  - Twenty two missions in Pre-Formulation/Formulation
  - Sixteen missions in Implementation
  - Advocacy with MSFC and KSC (so far!)
  - Group Evolution - Web Page efforts, Partnerships, Briefings
  - Partnerships in work with KSC, MSFC, NRO/OSL Directorate, SMC/TE, and JSC
For Further Information, Please Contact:

ATS Group Leader
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  William.E.Cutlip.1@gsfc.nasa.gov
  Voice: (301) 286-0438
  FAX: (301) 286-1696 0232

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  Thomas.S.Taylor.1@gsfc.nasa.gov
  Voice: (301) 286-8388
  FAX: (301) 286-0232
QUICK RIDE

ACQUISITION OVERVIEW

April 15, 1999

W. James Adams/401.5
301/286-1289
jim.adams@gsfc.nasa.gov
RSDO Program Themes

- Mission Project Manager/PI are THE CUSTOMER!
- Contract for What Industry has to Offer
- Fixed Price Orders With Necessary Insight
- Performance Based Milestone Completion Payments
- Allow Mission Unique Modifications to Basic Offerings
- Fair Opportunity to be Considered in Rapid Selection Process
- Volume of Orders Needed to Maintain Interest
- No Protests Allowed by FAR 16.505 (a)(7)
- Lessons Learned Folded into Service for Next Customer
History/Objectives

• Quick Ride is an Outgrowth of Rapid Spacecraft Acquisition
  – Multiple Task Order Contracts
  – Flight Service

• Provide a Variety of Low-Cost, Short Lead Time, Satellite Rides for Science Instruments:
  – Utilize Excess Space Available on Commercial Spacecraft

• Task Order Contracts with Commercial Firms That Will Permit Placing a Order Within 30 Days

• Secondary Objectives
  – Demonstrate a FAR Part 12 Commercial Acquisition
  – Explore the Use of On-Ramps
Market Research & Sources

• Rapid Spacecraft Market Research in March 1997 Indicated Some Interest in Selling Excess Payload Space
• Sources Sought Synopsis Issued June 1997 with Responses from 7 Companies
• 2nd Sources Sought Synopsis Issued March 18, 1998 with Responses from 10 Companies
• Market Research Confirms Commercial Service Approach
• RFO Reviewed by Code M&OSTP
Scope & Customer Base

- Scope
  - Define Rides Available Manifest and Minimum Order Time Before Launch
  - Carry Piggy-Back Secondary Instrument within Pre-Defined Parameters (Mass, Power, etc.)
  - Cost Range $2M-$4M for LEO Flight Service (GEO Goals $8M-$10M)
  - Fixed Price, Task Order Based Contracts
    - Interface Definition & Analyses
    - Integration & System Test
    - Launch
    - Initialization
    - 1 Year of On-Orbit Operations + Quarterly Options
  - Vendor Responsible for Obtaining all Export Licenses (Including the Secondary Payload)
  - Pre-Priced Accommodation Assessments (Studies)
Scope & Customer Base
(continued)

- LEO Technical Parameters
  - Mass 20Kg
  - Power 20 Watts
  - Data 2M Bits/Day

- Possible Customer Base
  - GISS/SPM, POEMS, UNEX, UESP, USAF Space Test Program, ESSP
  - NASA/GSFC, Other NASA Centers and Other Government Agencies (Consolidated Contract Initiative -- Intent to Procure Posted 3/31/98)
Based on Market Research

- User Instrument Must be Fully Compatible with Satellite
- User Caused Integration Problems May Result in Loss of Ride
- User Instrument Must Be On Time Or We May Be Left Behind
- Mission Could be Delayed Due to Primary Mission Problems
- Commercial Operations of Satellite Take Precedence Over Instrument Operation
- Government Has No Oversight and Minimal Insight into Processes, Procedures and Flight Readiness. Decision to Launch Rests with Commercial Satellite Contractor
Conditions, Constraints & Risks

• Short Lead Time to Identify Available Rides
• Flight Opportunities May Become Available Quickly -- Need to Identify and Complete Ride Selection Rapidly
• Instrument May Be Turned Off by Primary
• Payment Terms:
  – Technical Milestone Completion Based
  – Completion Criteria Defined in Task Order
• Financing Payments:
  – 60% of Task Order Value On-Orbit Performance Based
• NASA Conforms to the Market

Quick Ride Represents High Risk, Moderate Performance, Commercial Flight Opportunities at Very Low Prices
Industry Response

- Received Only One Offer (Expected 4 to 7 Offers)
  - Final Analysis Inc.
  - BAFO Evaluated and Selection Made July 15, 1998
  - Contract Awarded to Final Analysis Inc.
    - Options for 10 Rides Over 3 Years

- Statement of Intention to Use On-Ramp from 4 Others
Using the Quick Ride On-Ramp

- Will Evaluate Unsolicited & Solicited Proposals Based On
  - Technical Minimums
  - Price Reasonableness

- If a Vender Offers a Ride Involving a Non-US Country Based Launch System RSDO will Notify Code M/OSTP
  - Proposal will be Evaluated and if Appropriate, Contract Awarded
GEO Quick Ride

- NASA Desires to Promote Quick Ride on GEO Commercial Communications Missions
- Technical Feasibility Studies Underway
  - Lockheed Martin, Space Systems/Loral, Hughes Space and Communications, Orbital Sciences Corporation
  - Studies Wrap Up mid-May
- Results will be used to Assist Interested Satellite Owners to make Offers using Quick Ride On-Ramp
- Generic Interface Requirements Document for Science Teams Considering GEO Quick Ride
Spartan Project Overview
RideShare Conference

Donald E. Carson
Spartan Project Manager

April 15, 1999

E-mail: Don.Carson@gsfc.nasa.gov  Homepage: http://spartans.gsfc.nasa.gov/
Spartan’s Supporting Organizations

Long standing team with roots in NASA’s origins

- Sounding rockets
- Get-Away-Special (GAS) Program
- Spartan
- Hitchhiker
- SSBUV
- Pegsat
- Small Explorer Program - SAMPEX, FAST, SWAS, TRACE, WIRE
  - Including instrument management

3 lines of business closely associated with our current activities

- SMEX
- Hitchhiker
- Spartan
Spartan Project

Result of Office of Space Science requirement for a transition capability between sounding rockets and orbital missions

⇒ Started early in the Shuttle program
⇒ Project drew from suborbital program designs, GAS program and existing MSFC bridge and attach mechanisms

Features reusable Shuttle-based carriers
Spartan is an in-house project drawing support from a mix of support service contractors and matrixed discipline support from GSFC organizations

4/14/99
What do we do - top level

Provide an enabling capability for Space & Earth Science and technology experiments
Provide a frequent, low cost flexible vehicle for technology validation and technology infusion

How do we do it

Design, build, integrate, fly and reuse Shuttle-launched free-flyers for the science and technology communities

4/14/99 Spartan Project
What is the Spartan product line

The Project product line includes the Spartan 200 carrier and 4 Advanced Carriers in various states of development

- Spartan 200 - Autonomous 2 day mission, 1000 lb. instrument, flown 8 times
- Spartan 250 - Sp200 mechanical configuration with state-of-the-art avionics
  - Includes command and telemetry, 10 day mission
  - First mission, Sp251, funded by DoD, under development for flight in TBD
- Spartan Lite - Small non-recoverable satellite, 100 lb., 40 w. instrument
  - Shuttle side-wall mount offers frequent launch opportunities
  - Study went through carrier-only PDR/CDR
- Spartan 400 - Enabling capability for large instruments (1.5+ meter dia., 250+ w., 2000 lbs. class)
  - 1-3 year missions, orbit adjust/maintenance, recoverable/reusable
  - Generic carrier design has been through PDR
  - Phase A study for AF STP (nadir pointed) underway
  - Phase A study for NASA MIDEX effort, (solar pointed) underway
- Spartan 400/ISS serviced free-flyer - “entry level” Station serviced platform

4/14/99

Spartan Project
In addition, the Project provides

Customer Support

- AO support - the project supports all interested, feasible proposers for NASA AOs including:
  - SMEX
  - UNEX
  - MIDEX
  - Discovery
  - ESSP

- We are a national resource for the science and technology communities

- Other user support as required - DoD, NRO, Code M
# Summary Characteristics

<table>
<thead>
<tr>
<th>CAPABILITY</th>
<th>SP400</th>
<th>SP 250</th>
<th>SP-LITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission Lifetime</td>
<td>1 - 3 yr.</td>
<td>2 - 12 days</td>
<td>up to 1.5 yr.</td>
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<tr>
<td>Instrument Weight</td>
<td>2000 lbs.</td>
<td>1100 lbs.</td>
<td>100 lbs.</td>
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<td>Instrument Volume</td>
<td>60 in. diam.</td>
<td>60x50x30 in.</td>
<td>14 in. diam.</td>
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<tr>
<td></td>
<td>160 in. length</td>
<td>120 in. x 22 in. tube</td>
<td>40 W</td>
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<tr>
<td>Instrument Power</td>
<td>250 - 750 W</td>
<td>90 W</td>
<td>40 W</td>
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<tr>
<td>Solar Arrays</td>
<td>Deployed,</td>
<td>Deployed,</td>
<td>Fixed</td>
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<td></td>
<td>Articulated,</td>
<td>Articulated,</td>
<td></td>
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<td></td>
<td>Fixed</td>
<td>Fixed</td>
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<td>Uplink/ Downlink</td>
<td>2 kbps/2 Mbps</td>
<td>2 kbps/2 Mbps</td>
<td>2 kbps/2 Mbps</td>
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<td>Instrument C&amp;DH I/F</td>
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<td>1553 or RS-422</td>
<td>1553 or RS-422</td>
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<td>Pointing Accuracy</td>
<td>Arc-second</td>
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<td>Arc-second</td>
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<td>Retrieveable</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<td>Launch Vehicle</td>
<td>Shuttle</td>
<td>Shuttle</td>
<td>Shuttle/ELV</td>
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## Spartan Mission List

<table>
<thead>
<tr>
<th>Spartan number</th>
<th>Type of Mission</th>
<th>PI/Institution</th>
<th>Status</th>
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<tr>
<td>101</td>
<td>High Energy Astrophysics</td>
<td>Cruddace/NRL</td>
<td>Flown 6/85 (STS-51G)</td>
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<td>201-02</td>
<td>Coordinated observations - Ulysses</td>
<td>Kohl/SAO, Fisher/GSFC</td>
<td>Flown 9/94 (STS-64)</td>
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<tr>
<td>201-03</td>
<td>Coordinated observations - Ulysses</td>
<td>Kohl/SAO, Fisher/GSFC</td>
<td>Flown 9/95 (STS-69)</td>
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<tr>
<td>201-04</td>
<td>Calibration Flight - SOHO</td>
<td>Kohl/SAO, Fisher/GSFC</td>
<td>Launched 11/97 (STS-87)</td>
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<td>201-05</td>
<td>Calibration Flight - SOHO</td>
<td>Kohl/SAO, Fisher/GSFC</td>
<td>Flown 10/98 (STS-95)</td>
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<td>203</td>
<td>UV Observation of Comet Halley (Lost with Challenger)</td>
<td>Barth/LASP</td>
<td>Lost 1/86 (STS 51-L)</td>
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<tr>
<td>204</td>
<td>UV Astronomy (Stellar)</td>
<td>Carruthers/NRL</td>
<td>Flown 2/95 (STS-63)</td>
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<tr>
<td>206 (OAST-Flyer)</td>
<td>Technology Experiments</td>
<td>Lorentson, Bauer/GSFC</td>
<td>Flown 1/96 (STS-72)</td>
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<td>207 (IAE)</td>
<td>Inflatable Antenna Experiment</td>
<td>Brown/JSC, McCaughey/UMd</td>
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<td>251 (XS-10)</td>
<td>Micro-sat technology demo</td>
<td>Veal/L'Garde</td>
<td>Flown 5/96 (STS-77)</td>
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<tr>
<td></td>
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<td>DOD</td>
<td>TBD</td>
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</tbody>
</table>

4/14/99

Spartan Project
Outline

- Shuttle Small Payloads Project Office (SSPPO) Introduction
  - Program Sponsors
  - Current Manifest

- Hitchhiker (HH) Program
  - Hitchhiker-Junior (HH-Jr) Program

- Get Away Special (GAS) Program

- Space Experiment Module (SEM) Program

- Program Costs

- Future Enhancements
Shuttle Small Payloads Project Office

• NASA’s Goddard Space Flight Center (GSFC) Shuttle Small Payloads Project Office (SSPPO) operates the Hitchhiker, Hitchhiker-Jr., Get-Away-Special (GAS) and Space Experiment Module (SEM) Projects for NASA’s Office of Space Flight.

• Contacts:

  • Payload Carriers Program, Code VA-A, KSC
    Charles Sawyer, Jr., (407) 867-4840

  • Hitchhiker/GAS Program Coordination, Code MO, HQ
    John Castellano, (202) 358-4423

  • Shuttle Small Payloads Project Office, Code 870.G, GSFC
    Chris Dunker, (301) 286-4271
Shuttle Small Payloads Project (continued)

- **Hitchhiker Payloads:**
  - Carrier provides for Orbiter side-mounting or cross-bay mounting options
  - Experiments may be mounted in canisters, side plates, or top-mounted pallets
  - Standard, easy-to-use mechanical and electrical interfaces
  - Orbiter-provided power, command and data services available

- **Hitchhiker-Jr Payloads:**
  - Reduced version of Hitchhiker available for canister customers not requiring ground communications services

- **GAS Payloads:**
  - Self-contained payloads mounted in canisters only
  - Customer-provided power (battery) and data system required
  - Tertiary payload queue
  - Cannot require shuttle attitudes

- **SEM Payloads:**
  - Up to ten SEM Experiment Modules integrated into a single canister
  - SEM-provided structural support, power, command and data services
  - Tertiary payload queue
  - Cannot require shuttle attitudes
Active GSFC Shuttle Small Payloads (as of March 1999)

- **STS-96**: STARSHINE
  SVF-02

- **STS-101**: SEM-06
  MARS

- **STS-105**: HEAT
  CAPL3
  AMTEC-AWCS
  SIMPLESAT
  CONCAP-IV
  ACE-Jr.
  GAS (TBD x 2)

- **STS-107**: TAS-04/ISIS
  ISIS
  GAS (TBD x 1)
  SEM (TBD x 1)
Hitchhiker Program Description

- The Hitchhiker Program
  - Initiated by NASA’s Office of Space Flight in 1984
  - Quick reaction and low cost shuttle carrier service for small payloads
  - Simple, standard carrier to orbiter interfaces
  - Standard, user-friendly, carrier to customer interfaces
  - Reduce payload unique integration effort
  - Reduce lead time and recurring cost

- The Hitchhiker carriers consist of modular equipment designed for either side-mounting or cross-bay mounting in the shuttle payload bay

- Hitchhiker is sponsored by the NASA/HQ Office of Space Flight
  - No cost to a NASA user provided only standard services are required
  - Excess (optional) services are funded by the customer

- Hitchhikers are generally shuttle secondary payloads. Highly complex Hitchhiker carriers have also been manifested as primary payloads

- 24 Hitchhiker missions have been flown
Hitchhiker Mechanical Accommodations

- The Hitchhiker carriers consist of modular equipment designed for either side-mounting or cross-bay mounting in the shuttle payload bay

- Hitchhiker mechanical mounting provisions:
  - 5 Cubic Ft. Canisters – Max 200 lb. Payload Weight
  - 19" diameter x 28" height
  - Motorized Door Option
  - Side Mount Plate – Max 305 lb. Payload Weight
  - Top Plate – Max 600 lb. Payload Weight
Hitchhiker Ejection Systems

- Two Hitchhiker Ejection Systems may be used to launch small, non-hazardous customer payloads into shuttle orbit
  - Hitchhiker Ejection System (HES)
  - Pallet Ejection System (PES)
- Payloads up to 150 lb (68 kg), 19 inches (48 cm) in diameter and 20 inches (50 cm) high may be accommodated on a nine-inch clamp band launcher housed in a canister with or without a Hitchhiker Motorized Door Assembly
- Payloads up to 150 lb (68 kg) but with larger diameters can be launched on a Hitchhiker PES off the top of a cross-bay carrier
- No electrical connections to payloads are provided
- Neither HES nor PES provides for satellite spin-up
- HES has been used to launch GLOMR, NUSAT, BREMSAT, PAMS and MightySat 1
- PES has been used to launch SAC-A and PANSAT
Hitchhiker Ejection System Payload Envelope

- Lid (Closed)
- Payload Envelope
- Max. Diameter: 19.00
- Max. Height: 20.50
- 1.00 Min. Height
- C.G. Envelope
- 10.25 Max Height
- Payload Interface (See Next Figure)
- Ejection System (Man-Mach Not Shown)
Pallet Ejection System (PES)

Satellite Envelope

Pallet Ejection System

5.0 ft³

Pallet Configuration

Pallet Configuration
Hitchhiker Electrical Accommodations

• The current Hitchhiker Avionics System
  • Eight standard electrical interface “ports” for customer payloads
  • Each port provides the following:
    - 28V Power, Two 10A Circuits, up to 500W
    - Ground Command Interfaces
    - Time Signal
    - Low-rate Data Channel, up to 1200 Baud Downlink
    - Medium Rate Data Channel up to 1.4 MB Downlink

• Additional electrical services are optional including CCTV interface for on-board recording and downlink, or for crew display and control interface

• Payloads are operated from a Payload Operations Control Center (POCC) located at GSFC
Hitchhiker Transparent Data System

AT CUSTOMER'S FACILITY

CUSTOMER OPERATOR

CUSTOMER GROUND SUPPORT EQUIPMENT (CGSE)

CUSTOMER PAYLOAD

ADVANCED CARRIER CUSTOMER EQUIPMENT SUPPORT SYSTEM (ACCESS)

HH-1 AVIONICS

AT CUSTOMER/CARRIER INTEGRATION

CUSTOMER OPERATOR

CUSTOMER GROUND SUPPORT EQUIPMENT (CGSE)

AT FLIGHT OPERATIONS

CUSTOMER OPERATOR

CUSTOMER GROUND SUPPORT EQUIPMENT (CGSE)

MEDIUM RATE GROUND SUPPORT EQUIPMENT (MRGSE)

MISSION CONTROL CENTER

SHUTTLE ORBITER

HH-1 AVIONICS

CUSTOMER PAYLOAD

CUSTOMER PAYLOAD
Hitchhiker Thermal Experiment Requirements

- Each experimenter is responsible for the thermal design of their experiment.

- Each experimenter will provide to HH thermal analysis data that includes the following information:
  - A description of all surface coatings and multi-layer insulation (MLI) blankets
  - A **reduced** geometric and thermal math model of the experiment (approximately 50 surfaces and 20 nodes)
  - Temperature limits for all nodes in the thermal model for operating, non-operating and survival/safety cases
  - The size and location of heaters and the setpoints for the thermostats

- Each experimenter is responsible for providing their own thermal control coatings, MLI blankets, heaters and thermostats. HH provides the coatings and blankets on our plates, pallets, cans, and avionics.
Hitchhiker Thermal Deliverables

- **Thermal Models**
  - Experiment Reduced Thermal Models to be delivered to HH at L-15 months
  - Payload Reduced Thermal Models to be delivered to JSC at L-12 months
  - Payload Temperature Predictions and Capabilities to be delivered to JSC at L-12 months

- **Using the data supplied in the thermal models and reports, HH will provide inputs to the:**
  - Orbiter ICD Thermal Zone Chart and Surface Properties
  - PIP Capabilities Tables
  - Annex 2 Thermostatic Equipment Tables
  - Integrated Safety Analysis
  - Flight Rules
  - Mission Timeline Analysis
Hitchhiker Integration and Operations

- Ground operations flow at GSFC:
  - Hitchhiker customer equipment is typically integrated to the carrier at GSFC
  - System-level functional tests, EMI tests and telemetry tape tests are performed prior to shipping the integrated payload to KSC
  - POCC mission simulations conducted from the GSFC POCC
  - Customers provide personnel and Ground Support Equipment to operate their payloads during integration, mission simulations and flight
  - Ready for Shipment

- Ground operations flow at KSC:
  - Post-ship functional tests, thermal coating close-outs and sharp-edge inspections are performed at a KSC “off-line” Payload Processing Facility (PPF)
  - Orbiter installation occurs at the Orbiter Processing Facility (OPF) for horizontally processed payloads: at the Launch Pad for vertically-processed payloads
  - Orbiter Interface Verification Testing (IVT), final close-out of Remove-Before-Flight items, and a final sharp-edge inspection are performed at the Launch Pad
  - Ready for Launch
Hitchhiker Shuttle Process Scenario (Months)

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-24</td>
<td>Customer Organization Submits Form 1628</td>
</tr>
<tr>
<td>L-24</td>
<td>Customer Submits CPR to GSFC/SSPP</td>
</tr>
<tr>
<td>L-23</td>
<td>Customer Accommodation Meeting at GSFC</td>
</tr>
<tr>
<td>L-20</td>
<td>Customer Submits Preliminary Safety Data</td>
</tr>
<tr>
<td>L-7</td>
<td>Customer Submits Final Safety Data</td>
</tr>
<tr>
<td>L-6</td>
<td>Customer Hardware Delivered to GSFC</td>
</tr>
<tr>
<td>L-5</td>
<td>Customer/carrier Integration Completed</td>
</tr>
<tr>
<td>L-4.5</td>
<td>Hitchhiker Payload Shipped to Launch Site</td>
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<tr>
<td>L-3</td>
<td>Sidewall Hitchhiker Payload Installed in Orbiter</td>
</tr>
<tr>
<td>L=0</td>
<td>Launch</td>
</tr>
<tr>
<td>L+1</td>
<td>Customer Equipment Returned</td>
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</tbody>
</table>
HITCHHIKER-JUNIOR (HH-JR) PROGRAM
HH-Jr Program Description

- A reduced version of Hitchhiker (HH-Jr) is available for canister customers who do require ground communications services

- Mechanical and electrical Interfaces are similar to GAS

- Payloads are controlled by the crew during the mission. HH-Jr carrier provides display of carrier and customer engineering data (temperature, pressure, etc.) and has extensive crew command capability

- Approximately 100 W orbiter power available.
| L-18 Customer Organization Submits Form 1628 |
| L-17 Customer Submits CPR to GSFC/SSPP |
| L-16 Customer Submits Preliminary Safety Data |
| L-6 Customer Submits Final Safety Data |
| L-5 Customer Hardware Delivered to GSFC |
| L-4 Customer/Carrier Integration Completed |
| L-3 Payload Shipped to Launch Site |
| L-0 Launch |
| L+1 Customer Equipment Returned |
The Hitchhiker/Shuttle Process
Typical Hitchhiker Payload Document Deliverables

Prepared by GSFC/JSC with Experiment Inputs:

Payload Integration Plan (JSC)

PIP Annexes (JSC - inputs to all annexes required prior to CIR)
  Annex 1: Payload Data Package Annex
  Annex 2 Parts 1,2: Flight Planning Annex
  Annex 3: Flight Operations Support Annex (has been replaced by the Payload Operations Workbook)
  Annex 4: Orbiter Command and Data Annex
  Annex 5: Payload Operations Control Annex
  Annex 6: GSFC/Swales (replaced by Interface Control Annex)
  Annex 7: Training Annex (not typically required)
  Annex 8: Launch Site Support Plan
  Annex 9: Payload Verification Requirements Annex
  Annex 11: EVA Annex (not typically required)

Orbiter Interface Control Document (ICD), prepared by Boeing North America
Orbiter Installation Requirements Document (IRD), prepared by Boeing North America
Experiment to Carrier ICD's
Mission Operations Documentation
Typical Hitchhiker Payload Document Deliverables (continued)

Prepared by Experiment Organization and submitted to GSFC:

Customer Payload Requirements (CPR) Document
Flight and Ground Safety Data Packages
Reduced Thermal Model
Thermal Report
Fracture Control Implementation Plans
Fracture Control Summary
Drawing Package
Command Plan (draft - L-4 to L-6 mos, Final L-1 week.)
Nominal and Contingency Experiment Flight Operations Procedures
Technical Operating Procedures
PAO Experiment Summary and Line Art
GET AWAY SPECIAL (GAS) PROGRAM
GAS Program Description

- The GAS Program
  - Initiated by NASA’s Office of Space Flight in the mid-1970’s
  - Simple, Standard Carrier to Orbiter Interfaces
  - Standard, User-friendly, Carrier to Customer Interfaces
  - Minimum crew activity
  - No orbiter pointing requirements allowed
  - Opportunity manifesting only

- GAS carrier consists of 5 and 2.5 cubic foot canisters designed for either side-mounting (Adapter Beam Assembly) or cross-bay mounting (GAS Bridge Assembly) in the Shuttle Payload Bay

- GAS is sponsored by the HQ Office of Space Flight
  - First-in First-out Queue System
  - $27,000 cost to Non-NASA users
  - No Cost to a NASA User Provided Only Standard Services Are Required

- GAS payloads are always Shuttle tertiary payloads.

- 448 reservations; 28 customers have payloads in work
GAS Mechanical Accommodations

- The GAS carrier consists of 5 and 2.5 cubic foot canisters designed for either side-mounting (Adapter Beam Assembly) or cross-bay mounting (GAS Bridge Assembly) in the Shuttle Payload Bay.

- GAS Mechanical Mounting Provisions:
  - 5 Cubic Ft. Canisters – Max 200 lb. Payload Weight
    - 19" dia X 28" high
    - Motorized Door Option
  - 2.5 Cubic Ft. Canisters - Max 150 lb payload weight
    - 19" dia X 14" high
GAS Electrical Accommodations

• Electrical System
  • No orbiter power, data or command interfaces
  • Power must be provided via a user-supplied battery
  • Three crew-controlled (laptop) relays activate and deactivate GAS payloads
  • Simple pre-programmed control functions
  • Baroswitch to activate limited payload functions
GAS Thermal Experiment Requirements

- Each experimenter is responsible for the thermal design of their experiment.
- Sealed GAS canister typically provide a fairly benign thermal environment, thereby significantly reducing the complexity of the thermal analysis.
- Required data still includes the following information:
  - A description of all surface coatings and multi-layer insulation (MLI) blankets.
  - A reduced geometric and thermal math model of the experiment (approximately 50 surfaces and 20 nodes).
  - Temperature limits for all nodes in the thermal model for operating, non-operating and survival/safety cases.
  - The size and location of heaters and the setpoints for the thermostats.
- Each experimenter is responsible for providing their own internal thermal control techniques. HH provides the coatings and blankets on the canister exterior.
SPACE EXPERIMENT MODULE (SEM) PROGRAM
SEM Program Description

- The SEM Program
  - NASA educational initiative sponsored by the GSFC SSPPO
  - Provides nationwide educational access to space for Kindergarten through University level students
  - Experiments are created, designed, built and implemented by the students
  - Two standard mounting interface options: Simple, Standard Carrier to Orbiter Interfaces
  - Carrier-provided power, command and data storage options

- SEM carrier consists of a 5 cubic foot canister housing up to ten separate SEM Experiment Modules

- SEM is sponsored by the GSFC SSPPO
  - First-in First-out Queue System
  - No cost to qualified educational institutions

- SEM payloads may be Shuttle secondary or tertiary payloads

- Six SEM payloads (fully loaded canisters) have flown
SEM Mechanical Accommodations

- The SEM carrier consists of a standard 5 cubic foot canister containing ten separate SEM Experiment Modules

- SEM Experiment Module Mechanical Mounting Provision:
  - Use of NASA-provided Space Capsules to contain passive test articles
    - Clear, 1’ x 3” sealed plastic vials (0.5” capsule neck size)
    - Up to 22 vials may be packed in an individual Experiment Module using silicon foam cushion
  - Use of the SEM Experiment Module cover as an Experiment Mounting Plate (EMP)
    - The experiment envelope is precisely defined by the area delineated on the inboard surface of the EMP and a depth of 3.25” perpendicular from the surface of the EMP
    - Experiments are designed to be mounted to the surface of the EMP using NASA-provided integration hardware
SEM Electrical Accommodations

- SEM Active Experiments:
  - Power, command and data recording capabilities provided by the SEM Module Electronics Unit (MEU)
  - One crew-controlled (laptop) relay activates and deactivates a SEM canister
  - Temperature profile monitoring capability available via NASA-provided thermistors
  - Simple pre-programmed control functions
  - On-board data recording only; no telemetry feedback

- SEM Passive Experiments:
  - Do not require power, command and data recording capabilities
SEM Thermal Experiment Requirements

- Each experimenter is responsible for the thermal design of their experiment.

- Each experimenter is responsible for providing their own internal thermal control techniques. HH provides the coatings and blankets on the canister exterior.

- Temperature profile monitoring is available post-flight, via NASA-provided thermistors.
PROGRAM COSTS
Program Costs

- **Hitchhiker**
  - Sponsored by the Office of Space Flight, KSC Payload Carriers Program Office
  - No cost to NASA users provided only standard services are required
  - Standard services are described in the Hitchhiker “Customer Accommodations and Requirements Specifications (CARS)” document
  - Optional services assessed on a case-by-case basis
  - DoD payloads: approximately $400K per experiment. Funded by USAF Space Systems Division JSC/ZR for standard integration services
  - Foreign reimbursable: shuttle mission cost $0.0078 per mounting slot; previously about $1.2M (as of 1992)

- **GAS**
  - Sponsored by the Office of Space Flight, KSC Payload Carriers Program Office
  - No cost to NASA users provided only standard services are required
  - $27,000 cost to non-NASA users ($10,000 cost for U.S. educational institutions)
  - First-in First-out queue system

- **SEM**
  - Sponsored by the Office of Space Flight, KSC Payload Carriers Program Office
  - No cost to qualified educational institutions
  - First-in First-out queue system
FUTURE ENHANCEMENTS
Future Enhancements

- **Advanced Carrier Electronics (ACE)**
  - Supports up to 61 experiments
  - Supports PDI data rate: 8, 16, 32 Kbit/sec (configurable during mission)
  - Supports medium rate data archiving and playback during mission (up to 1 Mbit/sec)
  - Supports medium rate data up to 1.8 Mbit/sec
  - Provides system redundancy
  - Provides time tagged command / pre-stored command capabilities
  - Provides enhanced experiment interface
Future Enhancements

- **Shuttle Hitchhiker Ejection System (SHELS)**
  
  - Co-sponsored development by NASA/GSFC and DoD (USAF SMSC/OL-AW)
  
  - Side-mounting shelf designed to eject up to a 400 lb (maximum) satellite from the Shuttle Payload Bay
  
  - Center of gravity 24 inches above the separation plane; +/- 0.25 inches off ejection axis centerline
  
  - Payload envelope:
    - 42.0” (orbiter +/-x )
    - 26.0” (orbiter +/-y)
    - 45.0” (orbiter +/-z)
  
  - Power and data umbilical available
  
  - 280 Watts radiated heater power if no umbilical
Future Enhancements

- Shuttle Hitchhiker Ejection System (SHELS) Payload Envelope
Future Enhancements

- **International Space Station (ISS) Hitchhiker External Attached Payload Concepts**

  - ISS will be able to accommodate carriers such as Hitchhiker and GAS
  - SSPP concept provides carrier systems with standard Hitchhiker-type interfaces to allow flight of existing instruments
  - Carrier system to be accommodated on Express Pallet, Japanese Experiment Module, and other mounting options to be determined
Summary Comparison of SSPP Projects
## Comparison of Hitchhiker, Hitchhiker-Jr., GAS, CAP and SEM Carrier Requirements

<table>
<thead>
<tr>
<th>CAPABILITY</th>
<th>HITCHHIKER</th>
<th>HITCHHIKER-JR</th>
<th>SEPARATION SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Category</td>
<td>Primary/Secondary</td>
<td>Secondary</td>
<td>Secondary</td>
</tr>
<tr>
<td>Max Customer Weight (lb)</td>
<td>3000</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>Payload Mounting</td>
<td>Canister; Side Plate; Single Bay Pallet (SBP); Double Bay Pallet (DBP)</td>
<td>Canister</td>
<td>HES: Canister (Door/No Door)</td>
</tr>
<tr>
<td>Subsystems</td>
<td>PWR, CMD/TLM</td>
<td>PWR, Limited CMD/TLM</td>
<td>PES: Canister (Door/No Door); Single Bay Pallet (SBP); Double Bay Pallet (DBP)</td>
</tr>
<tr>
<td>Supplied Power (watts)</td>
<td>HTR PWR 1500W</td>
<td>HTR PWR 100W</td>
<td>No PWR, No CMD/TLM</td>
</tr>
<tr>
<td>Uplink Commands</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Downlink Data (max)</td>
<td>1.4 Mb/s</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Crew Control</td>
<td>Option</td>
<td>PGSC/BIA</td>
<td>SSP</td>
</tr>
<tr>
<td>Crew Display</td>
<td>Option</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Payload Unique Attitudes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Pallet Configuration

- Pallet Configuration

### Can Configuration

- Can Configuration
## Comparison of Hitchhiker, Hitchhiker-Jr., GAS, CAP, and SEM Carrier Requirements

<table>
<thead>
<tr>
<th>CAPABILITY</th>
<th>GAS</th>
<th>CAP</th>
<th>SEM</th>
</tr>
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<tbody>
<tr>
<td>Payload Category</td>
<td>Tertiary</td>
<td>Secondary</td>
<td>Tertiary</td>
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<tr>
<td>Max Customer Weight (lb)</td>
<td>200</td>
<td>200</td>
<td>6 per module</td>
</tr>
<tr>
<td>Payload Mounting</td>
<td>Canister</td>
<td>Canister</td>
<td>60 per payload Module</td>
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<tr>
<td>Subsystems</td>
<td>No</td>
<td>No</td>
<td>Battery, Fuse Box,</td>
</tr>
<tr>
<td>Supplied Power (watts)</td>
<td>No</td>
<td>No</td>
<td>Support Structure</td>
</tr>
<tr>
<td>Uplink Commands</td>
<td>No</td>
<td>No</td>
<td>600W</td>
</tr>
<tr>
<td>Downlink Data (max)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Crew Control</td>
<td>3 Relays (APC)</td>
<td>PGSC/BIA</td>
<td>1 Relay (APC)</td>
</tr>
<tr>
<td>Crew Display</td>
<td>PGSC/BIA</td>
<td>PGSC/BIA</td>
<td>PGSC/BIA</td>
</tr>
<tr>
<td>Payload Unique Attitudes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Flight Assignment Working Group
Planning Manifest
MightySat Program

Information Briefing for NRO Rideshare Conference

16 April 1999
Mr Pete Thomas
Purpose/Outline

- Briefly Describe MightySat Program
- Review MightySat II.2 Payload Capability
- Discuss MightySat II.2 Manifest Process
- Identify Current II.2 Manifest Status
- Discuss II.1 and II.2 Launch Vehicle Interests
MightySat Description

GOALS:

- Demonstrate AFRL Technologies
  - Where space flight required
- Provide Affordable Adaptable Platform to Customer Base
  - AFRL Technologies
  - Orbiting "Lab-bench" to Test High Payoff Mission Hardware
- Risk Reduction
  - Accept High-Risk Payloads
  - Spaceborne Platform to Illustrate Proof-of-Concept
    - Flight Heritage
    - Component-Level Test and Demonstration
- Develop AFRL's Internal Integration Capabilities
- Provide Experience to Junior Air Force Personnel
- Further and Transition Space Science & Technology

APPROACH: Series of Mission-Neutral SmallSat Flight Experiments

- 18-24 month Launch Centers
- AFRL provides experiments
- I&T at AFRL AEF
- Launch from Shuttle or OSP
- SMC/TE RSC Conducts Ops

STATUS: MSat I:

- Satellite Refurbished
- 5 Experiments integrated at AEF
- Shipped to GSFC Oct '97
- NASA Phase 2/3 Review Mar '98
- HES and Can Installation May '98
- Shipped to KSC Aug '98
- Launched: STS-88 4 Dec '98
- Successfully Deployed 14 Dec '98
- Satellite and Experiments Working Perfectly!

MSat II.1:

- 8 Experiments
- Completed CDR Feb '98
- AEF I&T Started Jun '98
- 4 Payloads Integrated by Oct '98
- 3 Other Payloads I/F Tested Dec '98
- Bus Delivered to AEF 28 Feb '99
- Launch on OSP 2 Apr '00

MSat II.2:

- Began Manifest Process Nov '98
- 56 Candidate Experiments To Date
- Focus is Key Distributed Aperture Technologies
What is MightySat II.2?

Program Office
- 1 Civilian, 3 Military, 3 Tech Support
- Within AFRL/VSDD
- Focussed on Mission Execution
- Not scientists or technologists

AFRL Tech Demo Mission
- List of Proposed Experiment Concepts
- STW/AR hardware built for MS II mission

Funding Line (FY00 to FY03)
- $29M POM; $16M after AFRL taxes/overhead
- $9.5M for Spacecraft Bus
- $1.5M for Integration & Test
- $2.7M for Launch and Mission Ops
- $2.3M for program office / technical support

Spacecraft Contract
- Spectrum Astro, Gilbert AZ
- Small Spacecraft Development Effort
- MS II.1 Bus Design (starting point)
- Some Spacecraft Parts (Lot Buys)
## II.2 Capabilities

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MS II.1 Capability</th>
<th>Upgrade Capability</th>
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</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>215-400 nmi</td>
<td>200-1000 nmi</td>
</tr>
<tr>
<td>Satellite Weight</td>
<td>285 lbs</td>
<td>400 lbs</td>
</tr>
<tr>
<td>Payload Weight</td>
<td>125 lbs</td>
<td>185 lbs</td>
</tr>
<tr>
<td>Satellite Power Gen</td>
<td>330 W</td>
<td>535 W</td>
</tr>
<tr>
<td>Payload Power Usage</td>
<td>70 W (avg)</td>
<td>200 W (avg)</td>
</tr>
<tr>
<td>External Payload Vol</td>
<td>20 x 24 x 18 &quot;</td>
<td>40 x 24 x 24&quot;</td>
</tr>
<tr>
<td>Pointing Knowledge</td>
<td>0.1 deg</td>
<td>0.1 deg</td>
</tr>
<tr>
<td>Pointing Control</td>
<td>0.2 deg</td>
<td>0.2 deg</td>
</tr>
<tr>
<td>Propulsion</td>
<td>None</td>
<td>TBD</td>
</tr>
<tr>
<td>Processor</td>
<td>RAD6000</td>
<td>RAD6000</td>
</tr>
<tr>
<td>Data Storage</td>
<td>380 Mbytes</td>
<td>1 GByte</td>
</tr>
<tr>
<td>Downlink Rate</td>
<td>1 Mbps</td>
<td>5 Mbps</td>
</tr>
</tbody>
</table>

Upgraded spacecraft capability will require additional program funding
Primary Constraints

Current Funding

$10M Bus limits spacecraft complexity / performance
$1M Launch budget limits mission orbit/mission life
  - Other launch options cost ~ $8M
$2M Operations budget limits mission complexity
Funding Profile limits schedule flexibility

Spacecraft Contract

- Scope of contracted effort (small satellite)
- Number of missions: 2 firm + 3 options

Technical Constraints

- STS launch system
  Ejection system limits volume / weight (400 lbs)
  Orbit limited to 200-300 nmi at 51.6 deg inclination
  Experimenter funding could relieve this constraint
- Current Bus design is not compatible with high-radiation orbits

AFRL Mission

- Primary Mission is for demonstration of AFRL technologies
- Experiments require AFRL sponsorship
II.2 Mission Development

- FY99 contains no funds for contracted spacecraft development
- MightySat does not fund payload development
- Space vehicle integration & test performed at KAFB
II.2 Launch & Operations

Launch

- Launch via ejection from Space Shuttle (baseline)
- But interested in higher altitude launch opportunities
- New ejection system under development by NASA
  - Accommodates moderate satellite growth from II.1
- Nominal ejection orbit: 210 nmi, 51.6 deg
- One year mission life mandates orbit-raising

Mission Operations

- Use of worldwide AFSCN ground sites
- SGLS-compatible system with 1 Mbps downlink
- Operations led by SMC/TEO
- Operations center at KAFB
II.2 Payload Manifest Process

Payload Concepts & Ideas
AFRL Tech Directorates
Other Agencies
DOE
Industry
Academia

Initial Review of Proposed Payloads

Directed Efforts for Payload Identification

MightySat II.2 Mission Design

AFRL, AF, DoD SERB

31 Oct 98  Nov - Jan 99  8 Feb 99  Feb-Aug 99  Sep 99
Payload Selection Considerations

**Programmatic**
- AFRL Priority / AFRL Support
- Diversity of AFRL sponsorship
- Importance to User Community
- Funding availability/potential
- Compatibility with MightySat Schedule
- Connections to External Agencies

**Technical**
- Need for 1-year Space Demonstration
- Compatibility with Mission Constraints
- Compatibility with available payload resources
- Synergy with other manifested payloads
- Technology Maturity
- Risk to satellite or overall mission
MightySat II.2 Manifest Status

- Received Approx 60 Candidate Experiments
- SAB - Provided Guidance
  - MightySat II.2 Very Favorably Endorsed
  - Focus of Key Distributed Aperture Technologies
- Have Held Several Discussions With NRO/AS&T
  - Coordinating Enhanced GPS Receiver Payload
- Manifest Effort Continues till Aug '98
  - TechSat 21 MSat II.2 Manifest Workshop 29-30 Apr
  - Other Possibilities Being Explored
MightySat II.1 & II.2 Launch Vehicle Interest

- **II.1 Sole Payload on Schedule for OSP2 - Mar ‘00**
  - Program Unsuccessful in Attempting to Rideshare on OSP2 or on Other Potential Launch Vehicles
  - Current STP Funding “Challenges” Exist with OSP2
  - Highly Dependent on OSP1 Success

- **II.2 Baselined for Shuttle - Apr ‘02**
  - Not Yet Manifested on STS (too early)
  - Other Launch Vehicle with Higher Altitude Preferred
    - Available Funding Extremely Limited
Summary

- Briefly Described MightySat Program
- Described MightySat II.2
- Provided MightySat II.2 Payload Capability
- Discussed MightySat II.2 Manifest Process
- Identified Current II.2 Manifest Status
- Discussed II.1 and II.2 Launch Vehicle Interests
CONTENTS

• Introduction to Spectrum Astro
• Spectrum Astro Spacecraft Busses
  - SA-200S
  - SA-200B
  - SA-200HP
  - SA-200L
• Discussion Topics for "Proprietary Session"
• Spectrum Astro Points-of-Contacts
# SPECTRUM ASTRO OVERVIEW

Multiple Strategies Utilized to Control and Reduce Cost

<table>
<thead>
<tr>
<th>SATELLITE SYSTEMS</th>
<th>SPACE ELECTRONICS</th>
<th>FLIGHT DATA STORAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Satellite System" /></td>
<td><img src="image2.png" alt="Space Electronics" /></td>
<td><img src="image3.png" alt="Flight Data Storage" /></td>
</tr>
</tbody>
</table>

- Full Service, Streamlined Space Systems Company
- Products Include Sophisticated Small to Mid-Size Satellites, Space Hardware, Ground Support, and R&D Products
- Employee Owned Business With Broad-Based Ownership
- High Productivity, Low Overhead: “Get-the-Job-Done” Culture
- 10 Yrs, 118 Successful Contracts, $140M Government Investment
- Consistent Successful Cost and Schedule Performance
- Award Winning Performance: Inc 500, SBA Prime Contractor-of-the-Year, Finalist Entrepreneurial Company-of-the-Year, Arizona Manufacturer of the Year

0000-EB-U00741
DEMONSTRATION SATELLITE HERITAGE
Technology Demonstration Satellites Are Our Core Business

HESSI
2000

MSTI
1 1992
2 1994
3 1996

CORIOLIS
2001

DS1
1998

2000
1 2002
2 2003
3 2003
4 2004
5

MightySat II

- Axis/Sun-Vector Spinner
- LEO/Interplanetary
- IR Payloads
  - Multispectral
  - Hyperspectral
- Passive Microwave
RECENT SPECTRUM ASTRO SUCCESSES

DEEP SPACE 1
Launched 24 Oct 98

STARDUST
Launched 7 Feb 99

LUNAR PROSPECTOR
Launched 6 Jan 98

MARS 98
Orbiter Launched 11 Dec 98
Lander Launched 3 Jan 99

MIGHTYSAT
Integration Oct 98 - Mar 99

C&DH Subsystem

UL/DL

PDU/CCU

P/L ACE I/F
## SA-200S SPACE VEHICLE

### Spacecraft Configuration

- **Payload Volume:** 1.0 x 1.2 (base) x 1.3 m (Pegasus)
- **Payload Volume:** 1.2 x 1.4 (base) x 2.4 m (Athena)

### Three-View Configuration

### Spacecraft Capability

<table>
<thead>
<tr>
<th>Mission &amp; Program</th>
<th>SA-200S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Mass</td>
<td>200 - 300 kg</td>
</tr>
<tr>
<td>Sunlit Array Power (BOL)</td>
<td>150-300 Watts (body-mounted)</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>Pegasus, Taurus, Athena</td>
</tr>
<tr>
<td>Mission/Orbit</td>
<td>Any: LEO, MEO, HEO, GEO, Planetary (stellars ACS)</td>
</tr>
<tr>
<td>Lifetime</td>
<td>1 - 3 Years</td>
</tr>
<tr>
<td>Mission Effectiveness</td>
<td>&gt; 0.80</td>
</tr>
<tr>
<td>Redundancy Architecture</td>
<td>Single String w/Selected &amp; Functional Redundancy</td>
</tr>
<tr>
<td>Parts Program</td>
<td>883B / JAN TVX Upscreened B Space Materials</td>
</tr>
<tr>
<td>Product Assurance</td>
<td>Tailored 9858/NHB 5300.4 (ID-2)</td>
</tr>
</tbody>
</table>

### Payload Accommodations

- **Payload Mass:** Up to 200 kg
- **Payload Power, Avg/Peak:** 60/180 W
- **Payload Field of View:** 2π Steradian
- **Payload Data Handling:** Up to 25 Mbps
- **Payload Data Storage:** 64 Gbit
- **Data Downlink Rate:** 1-10 Mbps

### Guidance & Control

- **Attitude Control:** 3-Axis, Zero Momentum
- **Pointing Control:** ± 20 Arcsec (1σ)
- **Pointing Knowledge (RMS):** ± 1 Arcsec (1σ)
- **Pointing Modes:** sun, nadir, off-set, point track, inertial
- **Pointing Stability:** < 0.1°/sec
- **Orbit Knowledge:** ±100 m GPS
- **Orbit/Trajectory Control:** < ± 0.5 km, 25 kg-N2H4

### Command and Data Handling

- **Ground Control IF:** S-Band (X-Band Available)
- **Data Interface:** STDN/DSN
- **S/C & Payload Telemetry:** ≤ 2 Mbps
- **Commands:** Up to 2 Kbps
# SA-200B SPACE VEHICLE AND MIGHTYSAT II DESCRIPTION

## Payload Accommodations

<table>
<thead>
<tr>
<th>Payload Accommodations</th>
<th>Nominal</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission &amp; Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launch Mass</td>
<td>125 kg</td>
<td>200 kg</td>
</tr>
<tr>
<td>Sunlit Array Power</td>
<td>310 Watts</td>
<td>400 Watts</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>STS Hitchhiker, ALV Secondary, MSLS, Med Lite</td>
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<tr>
<td>Mission/Orbit</td>
<td>All: TEO, MEO, HEO, GEO (Stellar ACS)</td>
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<tr>
<td>Lifetime</td>
<td>1 Year</td>
<td>3 Years</td>
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<tr>
<td>Mission Effectiveness</td>
<td>&gt;0.8</td>
<td>&gt;0.9</td>
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<td>Redundancy Architecture</td>
<td>Single String w/ Selected &amp; Functional Redundancy</td>
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<tr>
<td>Parts Program</td>
<td>883B / JAN TXV Space Matls</td>
<td>Class-S, MSFC-527, MIL-975</td>
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<tr>
<td>Product Assurance</td>
<td>Tailored 8858/NHB 5300.4 (1D-2)</td>
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</table>

## Guidance & Control

<table>
<thead>
<tr>
<th>Attitude Control</th>
<th>3-Axis, Zero Momentum</th>
<th>Pitch Bias, Spin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing Control</td>
<td>&lt;0.23°</td>
<td>&lt;0.1°</td>
</tr>
<tr>
<td>Pointing Knowledge (RMS)</td>
<td>&lt;0.15°</td>
<td>&lt;0.05°</td>
</tr>
<tr>
<td>Pointing Stability</td>
<td>&lt;0.1°/sec</td>
<td>&lt;0.01°/sec</td>
</tr>
<tr>
<td>Orbit Knowledge</td>
<td>±1 Km Gnd Eph., ±100 m (GPS)</td>
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<tr>
<td>Orbit Control</td>
<td>PPT, N_2, N_2*</td>
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</tr>
<tr>
<td>Momentum Management</td>
<td>Magnetic, RCS</td>
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</table>

## Command and Data Handling

<table>
<thead>
<tr>
<th>Ground Control I/F</th>
<th>UHF</th>
<th>Secure SGLS/STDN</th>
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<tbody>
<tr>
<td>SAC &amp; Payload Telemetry</td>
<td>32 Kbps</td>
<td>256 Kbps</td>
</tr>
<tr>
<td>Commands</td>
<td>2 Kbps</td>
<td>32 Kbps</td>
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</table>
SA-200HP SPACE VEHICLE

Spacecraft Capability

<table>
<thead>
<tr>
<th>Feature</th>
<th>SA-200HP</th>
</tr>
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<tbody>
<tr>
<td><strong>Mission &amp; Program</strong></td>
<td></td>
</tr>
<tr>
<td>Launch Mass</td>
<td>300 - 500 kg</td>
</tr>
<tr>
<td>Sunlit Array Power (BOL)</td>
<td>800 - 3,000 Watts</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>Delta II, Taurus, Athena</td>
</tr>
<tr>
<td>Mission/Orbit</td>
<td>Any: LEO, MEO, HEO, GEO, Planetary (stellar ACS)</td>
</tr>
<tr>
<td>Lifetime</td>
<td>3-5 years</td>
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<tr>
<td>Mission Effectiveness</td>
<td>&gt;.85 -.95</td>
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<tr>
<td>Redundancy Architecture</td>
<td>Single String w/ Selected &amp; Functional Redundancy</td>
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<tr>
<td>Parts Program</td>
<td>883B / JAN TXV Upscreened B Space Materials</td>
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<tr>
<td>Product Assurance</td>
<td>Tailored 9558/NHB 5300.4 (1D-2)</td>
</tr>
<tr>
<td><strong>Payload Accommodations</strong></td>
<td></td>
</tr>
<tr>
<td>Payload Mass</td>
<td>Up to 300 kg</td>
</tr>
<tr>
<td>Payload Power, Avg/Peak</td>
<td>800 / 1,800 W</td>
</tr>
<tr>
<td>Payload Field of View</td>
<td>2π Steradian</td>
</tr>
<tr>
<td>Payload Data Handling</td>
<td>&gt; 24 Mbps</td>
</tr>
<tr>
<td>Payload Data Storage</td>
<td>160 Mbyte to 60 Gbit</td>
</tr>
<tr>
<td>Data Downlink Rate</td>
<td>1-10 Mbps</td>
</tr>
<tr>
<td><strong>Guidance &amp; Control</strong></td>
<td></td>
</tr>
<tr>
<td>Attitude Control</td>
<td>3-Axis, Zero Momentum</td>
</tr>
<tr>
<td>Pointing Control</td>
<td>± 20 Arcsec (1σ)</td>
</tr>
<tr>
<td>Pointing Knowledge (RMS)</td>
<td>± 1 Arcsec (1σ)</td>
</tr>
<tr>
<td>Pointing Modes</td>
<td>sun, nadir, off-set, point track, inertial</td>
</tr>
<tr>
<td>Pointing Stability</td>
<td>&lt; 0.01°/sec</td>
</tr>
<tr>
<td>Orbit Knowledge</td>
<td>± 5 cm Radial (Differential GPS)</td>
</tr>
<tr>
<td>Orbit/Trajectory Control</td>
<td>&lt;0.5 km, 22-50 kg-N2H4</td>
</tr>
<tr>
<td>Momentum Management</td>
<td>Magnetor &amp; RCS</td>
</tr>
<tr>
<td><strong>Command and Data Handling</strong></td>
<td></td>
</tr>
<tr>
<td>Ground Control IF</td>
<td>S-Band, X-Band Down</td>
</tr>
<tr>
<td>Data Interface</td>
<td>STDN/DSN</td>
</tr>
<tr>
<td>S/C &amp; Payload Telemetry</td>
<td>≤ 8 Mbps</td>
</tr>
<tr>
<td>Commands</td>
<td>Up to 2 Kbps</td>
</tr>
</tbody>
</table>

Stowed Configuration

Deployed Configuration

Payload Volume = 1.0 x 1.2 (base) x 1.3 m (Pegasus)
1.2 x 1.4 (base) x 2.4 m (Athena/Other)
# SA-200LL SPACE VEHICLE

## Spacecraft Capability

<table>
<thead>
<tr>
<th><strong>Mission &amp; Program</strong></th>
<th><strong>SA-200LL</strong></th>
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</thead>
<tbody>
<tr>
<td>Launch Mass</td>
<td>450 - 840 kg</td>
</tr>
<tr>
<td>Sunlit Array Power (BOL)</td>
<td>1.200-1,500 Watts</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>Delta II, Taurus, Athena</td>
</tr>
<tr>
<td>Mission/Orbit</td>
<td>Any: LEO, MEO, HEO, GEO, Planetary (stellar ACS)</td>
</tr>
<tr>
<td>Lifetime</td>
<td>&gt;5 years</td>
</tr>
<tr>
<td>Mission Effectiveness</td>
<td>&gt;0.85 - &gt;0.95</td>
</tr>
<tr>
<td>Redundancy Architecture</td>
<td>Full Redundancy</td>
</tr>
<tr>
<td>Parts Program</td>
<td>8836 JAN TXV Upscreened B Space Materials</td>
</tr>
<tr>
<td>Product Assurance</td>
<td>Tailored 9858/NHB 5300.4 (1D-2)</td>
</tr>
</tbody>
</table>

## Payload Accommodations

<table>
<thead>
<tr>
<th><strong>Payload Accommodations</strong></th>
<th><strong>SA-200LL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Mass</td>
<td>Up to 500 kg</td>
</tr>
<tr>
<td>Payload Power, Avg/Peak</td>
<td>300 / 1000 W</td>
</tr>
<tr>
<td>Payload Field of View</td>
<td>&gt; 2π Steradian</td>
</tr>
<tr>
<td>Payload Data Handling</td>
<td>500 Mbits</td>
</tr>
<tr>
<td>Payload Data Storage</td>
<td>160 Mbyte to 60 Gbit</td>
</tr>
<tr>
<td>Data Downlink Rate</td>
<td>1-20 Mbps</td>
</tr>
</tbody>
</table>

## Guidance & Control

<table>
<thead>
<tr>
<th><strong>Guidance &amp; Control</strong></th>
<th><strong>SA-200LL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude Control</td>
<td>3-Axis, Zero Momentum</td>
</tr>
<tr>
<td>Pointing Control</td>
<td>± 20 Arcsec (1σ)</td>
</tr>
<tr>
<td>Pointing Knowledge (RMS)</td>
<td>± 1 Arcsec (1σ)</td>
</tr>
<tr>
<td>Pointing Modes</td>
<td>sun, nadir, off-set, point track, inertial</td>
</tr>
<tr>
<td>Pointing Stability</td>
<td>&lt; .01°/sec</td>
</tr>
<tr>
<td>Orbit Knowledge</td>
<td>± 5 cm Radial (Differential GPS)</td>
</tr>
<tr>
<td>Orbit/Trajectory Control</td>
<td>&lt; 0.5 km, 16 kg-N2H4</td>
</tr>
<tr>
<td>Momentum Management</td>
<td>Magnetic &amp; ROS</td>
</tr>
</tbody>
</table>

## Command and Data Handling

<table>
<thead>
<tr>
<th><strong>Command and Data Handling</strong></th>
<th><strong>SA-200LL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Control IF</td>
<td>S-Band, X-Band Down</td>
</tr>
<tr>
<td>Data Interface</td>
<td>STDN/DSN</td>
</tr>
<tr>
<td>S/C &amp; Payload Telemetry</td>
<td>≤8 Mbps</td>
</tr>
<tr>
<td>Commands</td>
<td>Up to 2 Kbps</td>
</tr>
</tbody>
</table>

5/14/1999
SPECTRUM ASTRO POINTS-OF-CONTACT

• Howard Parks, Director of Marketing
  (480) 692-8200
  howard.parks@specastro.com

• Dom Conte, East Coast Office Manager
  (703) 742-7876
  dom.conte@dchub.specastro.com

• Scott Yeakel, Director of Military Programs
  (480) 692-8200
  scott.yeakel@specastro.com
Low-Cost Space Platform
(technology demonstration, earth science, earth observation)

Presentation by
Integrated Space Systems Inc.

April 15, 1999

Integrated Space Systems Inc.
7940 Silverton Ave. Suite 202
San Diego, California 92126
(619) 684-3570 Fax: (619) 693-6932
Mission

Combine low-cost, versatile small satellites together with a low cost launch system to provide the customer with consistent, rapid access to space.

- Provide a standardized experiment platform
  - Maximum experiment flexibility
  - 1, 2, 3 or 4 stacked spacecraft
  - For a Total of 400 to 800 lbs of payload
  - matching to the customer's mission
- Launched on a low cost domestic launch vehicle
  - target access to space
  - target high radiation dose
  - target sun-synchronous
  - target special pointing requirements
- For the lowest possible cost per mission
  - For a single, all inclusive price,
  - Empowering the technology (payload) owner
  - With the least risk
Custom Solutions - Athena Example (multiple configurations)

Launch from WTR @ 90°

92" Fairing

2L
200 watts

2L
200 watts

800 - 1000 lbs to 600 nmi

Launch from ETR @ 28.5°

Notes:
- orbital lifetime ~ 8 months at 200 nmi
- orbital lifetime ≥ 10 years at 300+ nmi

800 lbs to 200 nmi

Athena-1

Athena-1B

10/23/98

MiniSIL™ Core Technology Platform

MiniSIL™

UNCLASSIFIED

ISS Proprietary Data Under PL 100-679 and/or FAR
Custom Solutions - Commercial Price List

6 Payloads per MiniSIL™ Shared Ride Options

Each MiniSIL provides 6 payload slots (total of 12 tickets)
5% discount for each additional slot used by the same payload

Includes:
- Project management, mission integration, spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options:
- Mission operations, ground systems, launch vehicle insurance, payload insurance

<table>
<thead>
<tr>
<th>Mission</th>
<th>Orbit</th>
<th>Payload Parameters</th>
<th>Cost Each</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incl. deg</td>
<td>Altitude km</td>
<td>Weight kg</td>
</tr>
<tr>
<td>Access to Space - short life</td>
<td>28.5</td>
<td>185</td>
<td>25</td>
</tr>
<tr>
<td>Access to Space - 5 year</td>
<td>28.5</td>
<td>600</td>
<td>25</td>
</tr>
<tr>
<td>High inclined</td>
<td>50.0</td>
<td>600</td>
<td>25</td>
</tr>
<tr>
<td>Sun Synchronous</td>
<td>SSO</td>
<td>600</td>
<td>25</td>
</tr>
</tbody>
</table>

25 kg = 55 lbs, 0.07 M³ = 4,300 in³
Custom Solutions - Commercial Price List

4 Payloads per MiniSIL™ Shared Ride Options

Each MiniSIL provides 4 payload slots (total of 8 tickets)
5% discount for each additional slot used by the same payload

Includes: Project management, mission integration, spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

<table>
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<th>Mission</th>
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<td>SSO</td>
<td>600</td>
<td>35</td>
</tr>
</tbody>
</table>

35 kg = 77 lbs, 0.1 M³ = 6,100 in³
# Custom Solutions - Commercial Price List

1 Payload per MiniSIL™ Individual Spacecraft Option

Each MiniSIL sold individually (total of 4 gold tickets)

Includes: Project management, mission integration, spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

<table>
<thead>
<tr>
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<th>Orbit</th>
<th>Payload Parameters</th>
<th>Cost Each</th>
</tr>
</thead>
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<tr>
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<td>600</td>
<td>55</td>
</tr>
<tr>
<td>Sun Synchronous</td>
<td>SSO</td>
<td>600</td>
<td>55</td>
</tr>
</tbody>
</table>

55 kg = 120 lbs, 0.20 M³ = 12,200 in³
Custom Solutions - Commercial Price List

6 Payloads per MiniSIL™ Shared Ride Options

Each MiniSIL provides 6 payload slots (total of 12 tickets)
5% discount for each additional slot used by the same payload

Includes: Project management, mission integration, spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

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<tr>
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</tr>
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</table>

25 kg = 55 lbs, 0.07 M³ = 4,300 in³
Custom Solutions - Commercial Price List

4 Payloads per MiniSIL™ Shared Ride Options

Each MiniSIL provides 4 payload slots (total of 8 tickets) 5% discount for each additional slot used by the same payload

Includes: Project management, mission integration, spacecraft, payload integration and test, launch vehicle, launch campaign and range costs

Unpriced Options: Mission operations, ground systems, launch vehicle insurance, payload insurance

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<td>Incl. deg</td>
<td>Altitude km</td>
<td>Weight kg</td>
</tr>
<tr>
<td>Access to Space</td>
<td>28.5</td>
<td>185</td>
<td>35</td>
</tr>
</tbody>
</table>

35 kg = 77 lbs, 0.1 M³ = 6,100 in³
Program Status - Fulfilling the Mission

Our U.S. team has been formed and a low cost path to space has been found.

- Integration Contractor - Integrated Space Systems Inc. (SpaceDev)
- Spacecraft Contractor - Space Innovations Ltd. (SpaceDev)
- Launch Services Contractor - Lockheed Martin Astronautics

- Providing service directly to the payload owner
  - Slots (tickets) on multi-user spacecraft
  - Whole spacecraft on multi-spacecraft launch

- Utilize MiniSIL™ stacked spacecraft capability
  - Fully manifest a small launch vehicle launch
  - Sell payload rides and/or whole spacecraft in stack
  - Maintain consistent payload and launch vehicle interfaces
  - Develop and maintain a regular launch schedule for each mission type

- We are ready to take reservations
Custom Solutions - One Potential Path to Launch

1) FASTMAX Study
   Determine feasibility of multi-mission launch.
   Customer evaluation of ISS/SIL capabilities.

2) Contract to deliver spacecraft for launch.
   Program Management     ISS
   Integration Contractor  ISS
   LSIC                   ISS
   Mission Design         ISS
   Spacecraft Subsystems  SIL
   Spacecraft Bus         SIL
   Spacecraft Final I&A&T ISS
   Launch Vehicle         LMA
   Launch Support         LMA/ISS
   Ground Systems Provider optional
   Mission Operations     optional

3) Initial Launch Capability - ATP + 24 months
SpaceDev
Small
Spacecraft
MiniSIL™ Spacecraft Model Specific Features

MiniSIL-P shown. MiniSIL-L and MiniSIL-2L mount subsystem equipment outside of thrust cylinder which allows all of thrust cylinder inner diameter to be used by payload(s).

<table>
<thead>
<tr>
<th>Model</th>
<th>Octagon Outside Diameter (in)</th>
<th>Spacecraft Height (in)</th>
<th>Spacecraft Total Weight (lb)</th>
<th>Payload Weight (lb)</th>
<th>Payload Volume Dia. (in)</th>
<th>Payload Volume Height (in)</th>
<th>Payload Power (sunlit)</th>
<th>Data Rate* for Circular Orbit (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MiniSIL-P</td>
<td>43</td>
<td>25</td>
<td>220-330 lb</td>
<td>90-130 lb</td>
<td>36</td>
<td>12</td>
<td>up to 55W</td>
<td>3.8</td>
</tr>
<tr>
<td>MiniSIL-2P</td>
<td>43</td>
<td>50</td>
<td>330-440 lb</td>
<td>130-180 lb</td>
<td>36</td>
<td>35</td>
<td>up to 135W</td>
<td>3.8</td>
</tr>
<tr>
<td>MiniSIL-L</td>
<td>63</td>
<td>25</td>
<td>330-550 lb</td>
<td>140-270 lb</td>
<td>36</td>
<td>24</td>
<td>up to 80W</td>
<td>3.8</td>
</tr>
<tr>
<td>MiniSIL-2L</td>
<td>63</td>
<td>50</td>
<td>440-770 lb</td>
<td>200-400 lb</td>
<td>36</td>
<td>47</td>
<td>up to 200W</td>
<td>3.8</td>
</tr>
</tbody>
</table>

* Assumes
1) SIL low-cost S-Band ground station (2.4 meter dish) with Convolutional and Reed-Solomon encoding
2) SIL 5 watt S-band transmitter (2.25 GHz)
3) 5 deg minimum elevation angle and 6 dB link margin
MicroSIL™ Spacecraft Model Specific Features

Payload are mounted on payload shelf separated from spacecraft subsystems.
S = Standard
3 = 3 axis stabilized
G = Gravity gradient torque

<table>
<thead>
<tr>
<th>Model</th>
<th>Cube Outside Dimensions (in)</th>
<th>Spacecraft Height (in)</th>
<th>Spacecraft Total Weight (lb)</th>
<th>Payload Weight (lb)</th>
<th>Payload Volume (sunlit)</th>
<th>Payload Power</th>
<th>Data Rate* for Circular Orbit (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shelf (in)</td>
<td>Height (in)</td>
<td>200 nmi</td>
</tr>
<tr>
<td>MicroSIL-S</td>
<td>19.3x19.3</td>
<td>20.1</td>
<td>100-145 lb</td>
<td>40-65 lb</td>
<td>18.5x18.5</td>
<td>6.7</td>
<td>30W</td>
</tr>
<tr>
<td>MicroSIL-3</td>
<td>19.3x19.3</td>
<td>20.1</td>
<td>100-145 lb</td>
<td>30-55 lb</td>
<td>18.5x18.5</td>
<td>6.7</td>
<td>25W</td>
</tr>
<tr>
<td>MicroSIL-G</td>
<td>19.3x19.3</td>
<td>20.1</td>
<td>100-145 lb</td>
<td>25-50 lb</td>
<td>18.5x18.5</td>
<td>6.7</td>
<td>30W</td>
</tr>
</tbody>
</table>

* Assumes
1) SIL low-cost S-Band ground station (2.4 meter dish) with Convolutional and Reed-Solomon block encoding
2) SIL 2 watt S-band transmitter (2.25 GHz)
3) 5 deg minimum elevation angle and 6 dB link margin
Extended MicroSIL™ Spacecraft Model Specific Features

Payload are mounted on payload shelf separated from spacecraft subsystems.
LS = Large, spin stabilized
L3 = Large, 3 axis stabilized
XS = Extended, spin stabilized
X3 = Extended, 3-axis stabilized

<table>
<thead>
<tr>
<th>Model</th>
<th>Cube Outside Dimensions (in)</th>
<th>Spacecraft Height (in)</th>
<th>Spacecraft Total Weight (lb)</th>
<th>Payload Weight (lb)</th>
<th>Payload Volume (sunit)</th>
<th>Payload Power</th>
<th>Data Rate* for Circular Orbit (S-Band / X-Band Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroSIL-LS</td>
<td>23.5x23.5</td>
<td>24</td>
<td>120-180 lb</td>
<td>60-90 lb</td>
<td>22.5x22.5</td>
<td>10.5</td>
<td>50W</td>
</tr>
<tr>
<td>MicroSIL-L3</td>
<td>23.5x23.5</td>
<td>24</td>
<td>120-180 lb</td>
<td>50-80 lb</td>
<td>22.5x22.5</td>
<td>10.5</td>
<td>45W</td>
</tr>
<tr>
<td>MicroSIL-XS</td>
<td>23.5x23.5</td>
<td>31.5</td>
<td>155-220 lb</td>
<td>80-110 lb</td>
<td>22.5x22.5</td>
<td>18.5</td>
<td>75W</td>
</tr>
<tr>
<td>MicroSIL-X3</td>
<td>23.5x23.5</td>
<td>31.5</td>
<td>155-220 lb</td>
<td>70-100 lb</td>
<td>22.5x22.5</td>
<td>18.5</td>
<td>70W</td>
</tr>
</tbody>
</table>

* Assumes
1) S/L low-cost S/X ground station (2.4 meter dish) with Convolutional and Reed-Solomon encoding
2) S/L 2-watt S-band transmitter (2.2 GHz) and S/L 3-watt X-band transmitter (8.4 GHz)
3) Ground station antenna 5° and 40° minimum elevation angle at S-Band and X-Band respectively, with 6 dB link margin
NanoSAT Spacecraft Model Specific Features

Simple, small spacecraft designed for one year on-orbit lifetime and quick launch as a secondary ride opportunity.

- Spacecraft design weight < 25 lbs
- Passive thermal control
- Functional life 1 year
- Small arrays and rechargeable batteries

<table>
<thead>
<tr>
<th>Model</th>
<th>Cube Outside Dimensions (in)</th>
<th>Spacecraft Height (in)</th>
<th>Spacecraft Total Weight (lb)</th>
<th>Payload Weight (lb)</th>
<th>Payload Volume (Shelf Height (in))</th>
<th>Payload Power (sunit)</th>
<th>Data Rate* for Circular Orbit (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NanoSAT</td>
<td>10''</td>
<td>12''</td>
<td>25 lb</td>
<td>5 lbs</td>
<td>10.0 x 10.0</td>
<td>1.5</td>
<td>2.4 nmi 400 nmi 600 nmi</td>
</tr>
</tbody>
</table>

* Assumes
1) SIL low-cost S/X ground station (2.4 meter dish) with Convolutional and Reed-Solomon encoding
2) SIL 2-watt S-band transmitter (2.2 GHz) and SIL 3-watt X-band transmitter (8.4 GHz)
3) Ground station antenna 5° and 40° minimum elevation angle at S-Band and X-Band respectively, with 6 dB link margin
SIL Subsystems and Component Heritage

- **Australia’s FedSat**: MicroSIL Satellite
- **Danish ØRSTED satellite (for CRI)**: S-band transceivers
- **Pakistan BADR-B satellite (for SUPARCO)**: S-band transmitters, receivers, diplexer; on-board computer and software; power conditioning system, NiCd batteries; digital sun sensors, magnetometer; magnetorquer rods, attitude control system; ground station equipment
- **Argentinian SAC-C small satellite (for CONAE)**: 1W S-band transceivers, 5W S-band transmitter, 3W X-band transmitter
- **ESA PROBA small satellite (for Verhaert, Belgium)**: S-band equipment; SPARC-based on-board SIL computer; power system, batteries; S-band ground station
- **UK STRV-1a/b small satellites (for DRA)**: S-band equipment; sun and Earth sensors; attitude control system. Designed and manufactured the attitude sensors, Fan-beam Attitude Sensor Electronics (FASE) Spacecraft Attitude Control Electronics (SACE), S-Band Receiver and Diplexer, and Charge Detector Experiment (CDE).
- **French and German small satellites (for CNES and DASA)**: S-band patch antennas
- **Solar and Heliospheric Observatory (SOHO)**: Design and Development of the Command and Data Handling System (CDHS) for the Coronal Diagnostic Spectrometer (CDS) instrument. Development of the optimum detector interfaces, triple redundant transputer-based processing architecture and memory elements.
- **ERS-2 PCSUs, Envisat DEU and PCSUs**: Manufactured the Power Conditioning and Supply Unit (PCSU) for ERS-2, completed manufacture of the PCSU and Digital Electronics Units (DEU) for the next generation Environment remote sensing satellite (ENVISAT).
- **Spectrum-X JET-X Attitude Sensor PSU**: Designed and manufactured the Jet-X Attitude Sensor Power Supply Unit for the Russian Spectrum-X satellite. The power supply unit provides the regulated power to the Jet-X attitude sensor electronics including CCDs.
- **DRS (for ESTEC)**: Designed and manufactured the Data Relay System (DRS) spread spectrum modem for ESTEC.
- **Meteosat-3 Experiment**: Developed an experiment for the Meteosat-3 satellite launched in 1988 to monitor radiation at the experiment site and perform radiation effects monitoring of a TMS320 processor and various memory chips.
Point Design Example

Spacecraft Instrumentation and Capabilities

Multi Spectral Imager

- 15 meter resolution at 800 km
- 75 km swath
- 1000 sq.km. stored on board at full resolution

Store and Forward Data

- VHF/UHF
- Payload modem 38.4 K bits per second

Available Payload

- 22 lb (10.0 kg) of payload used
- 72 lb (32.8 kg) of payload mass available
- 16 watts used by primary experiments
- 15 watts margin depending on orbit selected
Point Design Example

**Attitude Control - Mode: 3 axis stabilized**

### Pointing accuracy

<table>
<thead>
<tr>
<th></th>
<th>Pointing</th>
<th>Roll</th>
<th>Pitch</th>
<th>Yaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>15 arc-sec</td>
<td>15 arc-sec</td>
<td>20 arc-sec</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.10°</td>
<td>0.10°</td>
<td>0.15°</td>
<td></td>
</tr>
<tr>
<td>Rates</td>
<td>16.5 (arc-sec)/sec</td>
<td>16.5 (arc-sec)/sec</td>
<td>33.0 (arc-sec)/sec</td>
<td></td>
</tr>
</tbody>
</table>

**Sensors / Actuators**

- 2 Star-tracker sensors diametrically mounted
- Global positioning system
- Reaction (momentum) wheels
- 2 digital sun sensors (SIL cots)
- Magnetometer (SIL cots)
- Magnetorquers (SIL cots)
# Point Design Example

## Power System
- **Solar Cells**: Gallium Arsenide
- **Batteries**: Nickel cadmium rechargeable
- **Power conditioner**: Fully redundant 28 volts (SIL cots)

## Communication
- **Spacecraft**: S-Band (NASA / ESA standard)
  - 1 M bit per second (SIL cots) @ 400 nmi
- **Imager**: X-Band (encrypted) (S-band used as backup)
  - 16 M bit per second @ 400 nmi
Point Design Example

Other Systems

Structure: Aluminum structure and skin - honeycomb design
Thermal: Passive thermal blankets
Data Handling System: Rad Hard - SPARC 32 bit processor (SIL cots)
Standardized Sep System: Compatible to other MiniSILs, LVs and SVs

Payload Volume

Cylindrical space
920 mm diameter x 300 mm depth
Points of Contact

Integrated Space Systems Inc.

Jack A. Rubidoux
JackR@spaceinc.com

Phone: (619) 684-3570
Fax: (619) 693-6932
7940 Silverton Ave. Suite 202
San Diego, California 92126
United States
www.spaceinc.com

Space Innovations Ltd.

A. Kim Ward
Ward@sil.com

Phone: 044-07000-772234
Fax: 044-1635-38785
The Paddock, Hambridge Road
Newbury, Berkshire,
England RG145TQ
www.sil.com

International Business Office

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Philip Smith
Chief Operating Officer
PhilS@spacedev.com
ISS and SIL Capabilities & Assets

Integrated Space Systems Inc.
San Diego, California

- Program Management
- Launch Services Integration Contractor
- Mission Design
- Spacecraft Final Assembly
- Launch Support

Space Innovations Ltd.
Newbury, England

- Spacecraft Bus
- Spacecraft Subsystems
- Ground Systems
Spacecraft Design, Assembly and Test Building - San Diego, California

1800 sq.ft. Class 100,000 spacecraft assembly clean room
2500 sq.ft. mechanical sub-assembly test and checkout area
1000 sq.ft. avionics sub-assembly test and checkout area
680 sq.ft. systems integration lab
860 sq.ft. concurrent engineering lab
1750 sq.ft. shipping and receiving area
840 sq.ft. corporate conference room
320 sq.ft. engineering conference room
300 sq.ft. mission control center
7700 sq.ft. engineering space
1350 sq.ft. offices

Total = 25,600 sq.ft. including services
Spacecraft Key Personnel

Jan King – V.P. Space Engineering (30 plus years)
- Schriever Chair Professor (endowed chair), Dept. of Astronautics, United States Air Force Academy
- Vice President, Technology, Qualcomm, Inc., Boulder, Colorado
- Vice President, Boulder Operations, Orbital Sciences Corporation
- Vice President for Space Technology, Member BOD and Founder, Skylink Corporation
- Aerospace Technologist, NASA/GSFC
- Vice President for Engineering, Member of the BOD, Co-founder of the Radio Amateur Satellite Corp., Washington, D.C.

Rex Ridenoure – Chief Mission Architect (20 plus years)
- Manager, Microcosm’s Space Systems Division
- Program Architect, NASA’s New Millennium Program
- Project and Mission Engineer on five projects, JPL
- Mission Planner for the Voyager-2 Neptune Encounter
- Mission Engineer on GEO comsats at Hughes and Hubble at Lockheed
Spacecraft Key Personnel

Len Culhane - Chairman of the Board, Space Innovations Ltd.
Professor Len Culhane was awarded the BSc (1st Hons.) in Physics and the MSc in Physics from University College Dublin. His PhD was awarded in Space Physics by University College London. His research expertise is in X-ray astronomy, solar physics, X-ray spectroscopy, X-ray detectors and space cryogenic systems. He has won Principal Investigator roles on NASA, ESA and Japanese scientific space missions for which he has developed novel instruments for spectroscopy in the X-ray, Extreme UV and Infra-red wavelength ranges. Some of his many accomplishments include:

- Head, Department of Space and Climate Physics of UCL
- COSPAR Commission E
- Advisory Panel ESA Space Science Department
- UK Particle Physics and Astronomy Research Council
- Fellow of the Royal Society, Royal Astronomical Society, Institute of Physics & Foreign Norwegian Academy
- Full Member International Academy of Astronautics
- Member International Astronomical Union, American Astronomical Society, American Geophysical Union, IEEE Professional Group on Nuclear Science
- Research Scientist/Member of the Research Laboratory, Lockheed Palo Alto Laboratory,
Spacecraft Key Personnel

Kim Ward - Director SIL (30 plus years)
Kim was one of the founders of SIL in 1984 and has been with the Company ever since. As Technical Director, he was responsible for initiating and overseeing all the sub-system, spacecraft and ground system developments undertaken by the Company. He is now Director of Marketing. Kim has authored or co-authored many papers on his activities including papers on the various sub-systems produced by SIL and numerous papers on small satellites. He is an active member of: the IAA (International Academy of Astronautics) Space Sciences Committee, Sub-Committee for Small Satellites; the UK Space Science Advisory Committee, the UK Space Science Technology Panel; the GERB Project Steering Group; and the SIL representative on ASTOS, the UK Trade Association for space SMEs. Some of his accomplishment include:

- Station Director of the NASA Ground Station in Kenya for the San-Marcos-C Italian/American satellite.
- Experiment Operations Co-ordinator, NASA, Goddard Space Flight Center.
- Development for the UK cameras on the International Ultraviolet Explorer satellite.
- Leader of the Ariel VI Troubleshooting Team formed to investigate the Ariel VI spacecraft
- Study Manager for feasibility studies of ROSAT, AMPTE and HIPPARCOS.
- Project Manager for the UK AMPTE spacecraft launched in 1984.
RideShare Approaches and Benefits

- Assumed types of rideshares
  - Co-Manifest: 2 spacecraft of relatively equal size
  - Secondary: Small payload(s) or spacecraft relative to primary
  - Multi-Manifest: 2 or more spacecraft of like size and function
  - Different standardized technical and contractual solutions for each

- Provides Users with increased launch flexibility / opportunities
  - Utilize excess payload capacity
  - Standardized payload interfaces / processes
  - Greater manifesting flexibility and efficiency

- Provide more affordable per-payload launch costs
  - Shared launch costs based on mass and volumetrics
  - Minimize non-recurring integration effort and expense
  - Minimize spacecraft shelf life and maintenance costs

- Can serve as price discriminator in competitive bidding
Athena Capacity For Rideshares

- Athena I to II performance gap allows margin for rideshares
  - Capability Comparison (lb):
    
    | Orbit          | Athena IIB | Gap | Athena IIIB |
    |----------------|------------|-----|-------------|
    | 100 nm, 28.5   | 1800       | 4400|
    | 300 nm, 90     | 920        | 2700|
  - Gaps create unused capacity for missions
  - Average performance margin: 15% to 40%

- Large payload fairing volume
  - 92"-Diameter in production; Athena I and II
  - 120"-Diameter build-on-need; Athena II only

- Payload-to-LV Electrical Interfaces
  - Telemetry: 10 Analogs and 10 Discretes
  - 5 continuity (checkout) loops and 5 separation indicators
  - 8 channels for customer-specified SV commands

- FASSN Shockless Separation System
  - Screw-driven decoupling system
  - Greater payload mounting flexibility with fewer dynamic constraints
RideSharing Concepts

**Circular Load-Bearing Dispenser**
- Vertical mast structure supports 1 or levels of adjacent S/Cs
- Used for identical S/C deployed into constellation

**Shelf-Dweller Side Mounting**
- Mission-unique shelf for secondaries on adapter outer wall
- Relatively inexpensive
- Pre-work C.G. and coupled loads
RideSharing Concepts (cont)

“Inter-Adapter” Secondary Spacecraft Mount

“Top-Shelf” Secondary Spacecraft Mount
RideSharing Challenges

- **Cost of integrating multiples, co-mans or secondaries**
  - NRE and recurring cost of integration structures and electrical systems
  - Secondary payload launch budget typically < $1M
  - Cost prohibitive without LMC or USG investment

- **Increased contracting risk**
  - "Contingent" contracting for first signing party
  - Primary vs. Secondary User rights

- **Matching orbits for 2 or more spacecraft**
  - Inclination
  - Altitude (mitigated by on-board propulsion)

- **Lack of industry standards: electrical, mechanical interfaces**

- **Launch date/window conflicts**

- **Spacecraft environment concerns**
  - Mutual impacts due to coupled loads
  - Possible electro-magnetic, thermal or shock incompatibilities

**Success Requires Industry Standards and User Commitment**
Athena/SpaceDev Teaming Pursuit

- Pursuing partnership to fly experiments
  - SpaceDev’s SIL stackable bus
  - Athena I, IB and II standard launch service
  - Goal: **Lowest-possible per mission cost to the User**

- Cost-efficiency through standardization
  - Standardized electrical/mechanical LV/bus interfaces
  - 3 or 4 standardized orbits
  - Static launch dates
  - Quantity-buy Athena launch services

- Multiple experiments per launch (ETR assumed)

<table>
<thead>
<tr>
<th>LV Configuration</th>
<th># S/C Buses</th>
<th>Experiment Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athena I</td>
<td>4–P’s or 2–2L’s</td>
<td>8–12 Payloads</td>
</tr>
<tr>
<td>Athena IB</td>
<td>4–L’s</td>
<td>4 dedicated buses</td>
</tr>
</tbody>
</table>

(Athena II required for some high-inclination missions)

- Streamlined facilitation of rideshares
  - Elimination of “primary” spacecraft program constraints
  - Takes LV and SV programs out of the brokering business
  - Affordability stimulates demand
Concluding Remarks

- Athena Program Viable and Competitive
  - Holding cost/price despite sales slump
  - 3 for 3 in operational launches
    - Lewis / Athena I mission - 20 Aug 97
    - Lunar Prospector / Athena II mission - 6 Jan 98
    - ROCSat / Athena I mission - 26 Jan 99
    - Sub-system and system performance nominal to date
      - Orbital accuracy to within ~0.5 km, 0.013°
  - Two sites activated on schedule
  - 1st launch from Kodiak Launch Complex August 2000
  - 3 launches currently on manifest, 2 more recently awarded

- Ridesharing makes sense provided:
  - Matched spacecraft programs are compatible
  - Customers willing to assume business risk for LV savings
  - Spacecraft integration solutions are standardized

- International competition drives price-to-win:
  - Domestic: < $2M
  - International: < $1M

- Athena fits well with SpaceDev for rideshares
  - Eliminates “middleman” constraints for Users
  - Provides lowest-cost solution
Orbital Spacecraft Buses

Regan E. Howard
Advanced Systems Department
301-428-6091
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MicroStar Technical Specifications

- Core Bus Features
  - Bus Dry Mass: 40.0 kg
  - Payload Mass Capability: 68.0 kg
  - Redundancy: Single string
  - Orbit: 700-1,000 km
- All Inclinations
  - Launch Vehicle Compatibility: Pegasus, Taurus, SELVS I and II
  - Typical Mission Lifetime: 3-5 Years
  - Delivery: 24 Months ARO
- Power Subsystem
  - Payload Power: 70 W orbit avg.
  - Bus Voltage: 14 VDC
    - 28V optional
  - Solar Arrays: 2 GaAs
  - Batteries: 10 A*hri NiH
- Attitude Control Subsystem
  - Stability Mode: 3-axis
  - Control: ± 1°
    - 0.02 ° per axis pointing optional
  - Knowledge: < 2°
  - Rate/Stability: < 0.01°/sec
• Customer: ORBCOMM Global
• Mission
  – Narrow Band, 2-Way Data for:
    • Monitoring
    • Paging
    • Tracking
    • Messaging
• Performance Summary
  – 5 Year Mission Goal
  – Uplink: VHF (148-150 MHz) at 2400 bps
  – Downlink: VHF (137-138 MHz) at 4800/9600 bps
• Status
  – Fully Licensed by FCC and ITU
  – Financed With ~$400M in Equity, Debt and International Partner Capital
  – Operational Now With Constellation of 28 Satellites
OrbView-4

OrbView-4 Spacecraft

Hyperspectral

Panchromatic

Multispectral

• Customer
  - ORBIMAGE

• Mission
  - Provide High-spatial Imagery
    • Panchromatic
    • Multispectral (4 Bands)
    • Hyperspectral
  - Applications
    • National Security
    • Mineral and Oil Exploration

• Performance Summary
  - 5-year Mission
    - Orbit, Circular: 705 km, 98°
    - 3-axis Control: +5 Arcsec (1σ)
    - Knowledge: +3 Arcsec (3σ)
  - Bus Mass: 290 kg
  - Payload Mass: 72 kg

• Status
  - In Development
  - Taurus Launch 2Q00
GALEX (Galaxy Evolution Explorer)

- Customer
  - NASA Small Explorer Mission
  - PI: Chris Martin/CalTech
  - Mission Management: JPL

- Mission:
  - UV telescope will perform all-sky survey
  - Investigate origin and evolution of galaxies, stars and heavy elements

- Performance Summary
  - 29 Month Mission
  - 1.2 Arc-min Pointing Accuracy
  - 0.1 deg/sec slew rate
  - Launched 9/01 Aboard PEGASUS XL
  - Mass 254 kg (S/C Plus Instruments)
  - Power 293 WOA array power EOL
  - Orbit 690 km Circular, 28.5° Inclination

- Status
  - Phase C/D
SAVE/SOLSTICE

• Customer
  – University of Colorado @ Boulder, Laboratory for Atmospheric & Space Physics

• Mission:
  – Continue the Solar Ultraviolet Spectral Irradiance Data Set
  – Measure Solar and Stellar Irradiance Variations
  – Investigate Their Effects on the Earth's Climate
  – SAVE is Part of NASA's Ongoing Earth Observation System(EOS) Program

• Performance Summary
  – 6 Year Design Life (Redundant components)
  – 0.24 Arc-min Pointing Accuracy
  – 1 deg/sec slew rate
  – Launched 7/02 Aboard PEGASUS XL
  – Mass 237 kg (S/C Plus Instruments)
  – Power 707 WOA array power EOL
  – Orbit 660 km Circular, 40° Inclination

• Status
  – In Phase B
GEO Quick Ride

- Orbital Was Awarded GEO Quick Ride Study Contract
  - Targeted at 2001 and Beyond Satellite Capabilities
  - Mid-Term Held in March 1999
  - Study Will Be Completed in May 1999

- Basis of Study:
  - NASA Science is Interested in Piggy Backing on Commercial Missions to GEO

- Orbital's Star-2 Bus Is Being Used For The Study
  - Star-2 Bus Is Capable of Accommodating Instruments Over the Entire Range Defined By NASA
  - Power Margins Can Be Exploited In The Accommodation of Instruments
  - Typical Configuration With Side Mounted Communication Payload Antenna Provide Excellent Field-of-View For Instruments

- Orbital Is Providing NASA With a Defined Set of Instrument Accommodation Parameters
Secondary Payload Fields of View

- With Earth Panel Mounted Antennas, a Variety of Earth Panel Mounting Locations Are Available With Clear Nadir Pointing 20° (Full Angle) Fields of View.
Small Platforms for Secondary Payloads

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Launch Integration Manager
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Sensor Platforms

- SSA
- GTD
- DARPSAT
- GFO
- RS2000
- Multi-spectral Thermal Imager
- QuickScat
SubSystem “A” (SSA)

- Shuttle launched - GAS Can
- Mission: Classified
- Customer: Classified
- Single-string
- Spin-stabilized
- 19” dia x 35” H
- 119 kg spacecraft
  - 23 kg payload
- 29 W array BOL
  - 55 W peak for payload
- SGLS (encrypted)
  - 32 kbps downlink
- Status: Launched 1989
  - 1 yr life/3.5 actual
“G” Test Demonstration (GTD)

- Shuttle launched - GAS Can
- Mission: Classified
- Customer: Classified
- Single-string
- Spin-stabilized
- 19” dia x 40” H
- 125 kg spacecraft
  - 20 kg payload
- 29 W array BOL
  - 57 W peak for payload
- SGLS (encrypted)
  - 32 kbps downlink
- Status: Launched in 1991
  - 1 yr life
Multi-Purpose Experimental Canister (MPEC)

- Ball-built dispenser for SSA and GTD
- **Mission:** Classified
- **Lifetime:** 1 yr. w/3 yr. Goal
- **Bus Weight:** 437 lbs.
  - 195 kg spacecraft
    - 39 kg payload
- **Launch Vehicle:** Taurus
  - dual launch with STEP
- **Dimensions:** 31” X 31” X 30”
- **70 W array**
  - 107 W peak for payload
- **Status:** Launched March 1994, still operational
• Taurus launch
• Fully redundant
• 3-axis stabilized
• 40” x 40” x 40”
• 350 kg spacecraft  
  – 60 kg payload
• 319 W array BOL  
  – 126 W for payload
• SGLS  
  – 4 Mbps downlink
• Status: Launched Feb. 1998  
  – goal 1 year in XX year goal
Aerospace Systems Division

LOSAT-X

• Customer: Strategic Defense Initiative Organization

• Ball Role
  – Turn-key Mission: satellite, launch
    vehicle integration, one on-site mission
    ops center, mission ops

• Mission
  – Obtain data from and perform calibration
    on sensors used on Brilliant Pebbles

• Unique, low-cost design
  – No redundancy - 3 month life on orbit
  – Bus: 148.3 lb, 4.3 x 3.3 x 1.5 ft
  – Delta II
  – Price $M
- Design Orbit: 600 Km at 52.5° Inclination
  Sun Synchronous Orbits examined
- Launch Vehicle: Multiple (Taurus Compat.)
- Payload Mass: 604 pounds
- Payload Power: 430 Watts Average
  Mission Scenario Dependent
- ADCS: 3 Axis Stabilized/Reaction Wheels,
  Gyros, Star Trackers, GPS
- Pointing Accuracy: 0.03°/axis
- Design Life: 5 years, Redundant
- Data Storage: 137 Gbits
- Propulsion: Hydrazine
- Downlink: 4, 16, 256 Kbps X-Band
  320 Mbps X-Band

Designed as an Earth Observation Satellite
The RS2000 can accommodate multiple payloads using an instrument module and can be co-manifested on a Delta-II

Delta II w/ DPAF

Taurus

Athena II
Multi-spectral Thermal Imager (MTI)

- Design Orbit: 525 Km; Sun Synchronous
- Launch Vehicle: Taurus
- Payload Mass: 550 pounds
- Payload Power: 271 Watts Average
- ADCS: 3 Axis Stabilized/Reaction Wheels, Gyros, Fine Sun Sensor, Horizon Scanner
- Pointing Accuracy: <.35°
- Life Time: 1 yr. w/3 yr. goal
- Data Storage: 2.8 Gbits
- Propulsion: None
- Downlink: 1, 2, 4, 8 Mbps Mission data (S-Band)
  2 and 16 Kbps S/C data only (UHF)

Customer: Sandia National Laboratory
Status:
QuickScat - RS2000 in Action

- NASA Quick Scatterometer
- Mission: Record sea surface wind speed and direction
- Lifetime: 2 yrs. W/ 3 yrs expendables
- Bus Weight: 650 kg (including propellant)
  - 220 kg payload mass
- Launch Vehicle: Titan II
- 803 km sun-synchronous orbit
- 2 - 3.2 square meter solar arrays
  - 255 Watts orbit average
- Status: Waiting for launch
  - Currently scheduled for May 29th
Modification of RS2000 Bus

- **Attitude Control System**
  - Pointing Accuracy: <0.3 deg; (3s) per axis
  - Pointing Knowledge: <0.027 deg; (3s) per axis

- **Transmit/receive rates CMD/TLM**
  - 4 and 256 kbps downlink
  - 2 kbps uplink

- **Payload Data**
  - 2 Mbps transmit rate
  - S-band frequency
• System type:
  – Hyrdazine
  – 4 thrusters 4.4 Newtons each
  – 76 kg of propellant

• Delta-V capability: 62 m/s
• Ball has concept designs for low cost secondary platforms for both 3 axis pointer and stabilized spinner

• Inquires for these platforms are welcomed
Lockheed Martin Missiles & Space (LMMS) Smallsat Capabilities

RideShare Conference
April 15, 1999

Ed McNamara
ed.mcnamara@lmco.com
408-742-2996
LMMS Smallsat Capability

- **LM100™ Class Busses**
  - Lunar Prospector baseline
  - IMAGE ‘stretched’ version
  - Gravity-Probe B ‘smaller’ version

- **LM700™ Class Busses**
  - Iridium baseline

- **LM900™ Class Busses**
  - CRSS (Ikonos) baseline
The Lunar Prospector being prepared for acoustic test.
Introduction

• LM100™ is derived from the Lunar Prospector spacecraft developed for NASA

LM100™ with payload masts deployed.

• LM100™ mission suitability:
  – Small, spin stabilized spacecraft
  – Boom mounted payloads
  – Payloads isolated from spacecraft

Launched: 6 Jan '98 on Athena 2 booster
Lunar Prospector Mission Overview

• Discovery Mission: Deliver science data to user community and demonstrate viability of the "faster, cheaper, better"
• Purpose: Lunar science and exploration to include crustal composition mapping, magnetic and gravity field maps, quantify polar ice deposits, search for evidence of lunar outgassing
• Baseline Mission: 1 year, 100 km lunar polar orbit
• Extended Mission: 7 month, 30 x 30 km circular orbit
• Payload Description: 5 omni directional science instruments, packaged as three independent payload elements
• Payload Accommodation:
  - 3 x 250 cm deployable longeron masts
  - 24 kg for science instrument (SI) packages (8 kg per mast tip plate)
  - 17 watts continuous power
  - Precision thermal control for Gamma Ray Spectrometer SI

Lunar Prospector Currently in Lunar Orbit
LM100™ Mission Capability

- Small scientific payloads to GEO, LEO* and lunar orbits
- 3 year mission life
- 141 kg dry mass, 300 kg launch mass
- DSN or TDRSS compatible S-Band CCSDS compatible communications
- Spacecraft and payload equipment mounting to primary bus structure. Ample area for installing electronics units
- Orbit maintenance provided by propulsion system.
- Upper stage compatibility (Star37 series solid rocket motor)
- 24 month schedule from ATP to delivery

*LEO orbit capability limited by ground station availability or on-board data storage capability.

Flexible spacecraft platform for small scientific payloads
LM100™ System Capabilities

- **Structures & Mechanisms**
  - Graphite/Epoxy primary and secondary structures: >12 Hz lateral and >30 Hz axial

- **Electrical Power**
  - Unregulated 28±6 Vdc system, 230 watt BOL solar array, single 5 Ahr NiCad battery

- **Thermal control**
  - 3 year design life, blankets and coatings, redundant heater circuits

- **Propulsion**
  - Hydrazine monopropellant, system ΔV = 1430 m/s

- **Attitude Control**
  - Spin Stabilized: 1.0° attitude knowledge, 2.0° spin axis pointing, 1.0° spin axis offset

- **Communication**
  - S-Band : 300 and 3600 bps down-link, 250 bps up-link; CCSDS format

- **Ground System and Software**
  - Vehicle commanding, telemetry processing for attitude determination and spacecraft health and status. 24 hr monitoring, DSN and GSFC navigation support.

---

*Simple, reliable spacecraft with minimal operational requirements*
LM100™ Configuration

- Lunar Prospector / LM100™ configuration with Trans-Lunar Injection (TLI) Stage.
- Launch configuration with payload booms stowed.
- Basic envelope: 241 cm long, 205 cm dia.
- 3 pt Spacecraft separation system, easily adapted to marmon clamp.
- Launch vehicle compatibility:
  Athena 1, Athena 2, Taurus, Delta, Atlas

A small, reconfigurable spacecraft.
IMAGE System Changes
(from LM100™)

**SPACECRAFT OVERVIEW**
- Near Autonomous Operation
- Multiple Science Capabilities
- Data Storage and Playback

**COMMUNICATIONS**
- 2 OMNI II antennas
- 2 RF Switches

**STRUCTURES**
- Aluminum honeycomb panels and gap shielding for EMI/EMC
- Flat panel solar arrays
- Modular payload deckplate

**ATTITUDE CONTROL**
- Star tracker provides autonomous attitude determination
- Torque rod controls both spin axis orientation and spin rate
- Magnetometer provides magnetic field orientation reference

**THERMAL CONTROL**
- Heat pipes through P/L dock to perimeter radiators
- Software controlled heaters

**ELECTRICAL POWER SUBSYSTEM**
- 21 Ah Battery dominated bus
- >320 watt SA capability at zero beta angle
- >230 watt SA capability at 67° beta angle
- >120 KHz SA current (shunt regulation)

**COMMAND & DATA HANDLING**
- R6000 based System Control Unit hosts flight software
- COP-2 compatible command uplink
- AOS CCSDS compatible telemetry downlink
- FSW functions include attitude control, general telemetry monitoring, power management and thermal control

System modifications provide robust enhanced capabilities

5/11/99
Small Spacecraft Configurations

Image

Gravity Probe B

Provides Enhanced Instrument Accommodation
The Iridium bus being prepared for test
LM700™—Standard Bus

- Derived from IRIDIUM® production line
  - IRIDIUM® contract with Motorola for 125 buses
  - First launch July 1996
- LM700™ features
  - Gr Ep structure—bus/electronics sections
  - Propulsion
    - Hydrazine reaction engine assembly thrusters for attitude control and back-up for orbit adjust
    - High lsp electro-hydrazine thruster (EHT) for orbit adjust
  - Attitude control system
    - Momentum bias
    - Three-axis gyro (TGA)—ring laser
    - Horizon sensors
    - Magnetic torque rods
    - Magnetometers
    - Reaction wheel
- Electrical Power System
  - 1200 W solar array (EOL)
  - Single 50AH NiH₂ battery

5/11/99
LM700™ Options

• **LM700™ options**
  - Shortened structure (2 bus modules)
  - Lengthwise orientation along velocity vector
  - Shortened solar arrays—60% and 80% power for Athena-1 234 cm (92”) shroud packaging (approx. 200 or 350 watts for payload - 500 W for full arrays)
  - Flight software modifications
  - Comm subsystems - SGLS or STDN
LM700™ On-Orbit Configurations

330 cm (130") full size solar panel

Electronics module ~ 193cm (76") long

LM 700-100

Bus module ~49" long

LM 700-200

FLIGHT +X

FLIGHT +X

NADIR +Z

NADIR +Z

LM 700-300

LM 700-400

FLIGHT +X

5/11/99

14
LM700™ Bus Capability

Structures
- Graphite epoxy composite frame
- Aluminum honeycomb core with graphite epoxy face sheets and shelving
- Modified mounting brackets and unique payload adapter

Attitude/orbit control
- 3-axis momentum bias control
- 7-0.2 lbf REA thrusters
- 1-0.08 lbf EHT thruster
- Hydrazine propellant/tank
- $\Delta V_{tot} = 675$ m/s

Electrical power
- 50 Ah (rechargeable) NiH$_2$ battery
- 2 deployable GaAs solar panels 960W (EOL) (80% arrays)
- 28V unregulated electrical bus

Communications options
- SGLS or STDN uplink/downlink
- 2 omni antennas

Command and data handling
- 12 MIPS R3000 flight computer
- Realtime and stored commands and telemetry
- Discrete, analog and 1553 payload IFs
- SEAKR 64 Mbyte solid state recorder

5/11/99

Thermal control
- Computer-controlled heaters (resistive)
- Passive thermal coatings, finishes, and MLI
- Battery radiator with feedback controlled variable conduction heat pipes
Sample LM700™ Configuration

Payload 1

Payload 2

523 cm. 206 in.

Roll/yaw thrusters

107 cm. 42 in.

348 cm. 137.2 in.

Pitch/orbit adjust thruster

5/11/99

SGLS antenna
Variable conductance heat pipes
Battery radiator
NiH₂ common pressure vessel battery
Booster separation fitting
Azimuth-elevation solar array gimbal
Solar array release mechanisms
Electro-thermal hydrazine thruster
Payload adapter
SGLS antenna
Roll/yaw thruster
Solar array circuit
GaAs solar array
LM700™ - 300/400 on Athena-1

- 230 kg. (500 lb) nominal payload to 650 km @ 28.5° inclination

- Payload Volume: 6000 cu. cm. (57 cu. Ft.) external
  1200 cu. cm. (11 cu. Ft.) internal

- Basis:
  640 kg (1400 lb.) Total spacecraft weight (wet)
  410 kg (900 lb.) LM700™ bus includes 250 lb. of propellant

- Nadir Payload Sensor Volume: 100cm D x 89cm L
- Pallet Payload Sensor Volume: 165cm L x 66cm W x 46cm H
- Internal Payload Volume: 160cm L x 48cm W x 28cm H
LM700™ Launch Vehicle Limits on Payload

• Athena-1
  – Most efficient operation - Boost to 100nmi and use LM700™ EHT to reach final orbit
  – Approximate limits for 500 km orbit
    • 57 deg. ~ 230 kg (500 lbs)
    • 70 deg. ~ 180 kg (400 lbs)
    • Sun synch. ~ 70kg (150 lbs.)

• Athena-2
  – Limit is LM700™ structure capability ~230 kg (500 lbs.)
The CRSS (Ikonos) bus being prepared for test.

5/11/99
CRSS® Heritage of LM900™

- **Customer:**
  - Space Imaging Inc.

- **Operation:**
  - Agile spacecraft to image arbitrary earth locations
  - Images collected by precision scan of linear array

- **Lockheed Martin Role:**
  - Prime contractor and system integrator
  - Space, ground and launch segment
LM900™ Basic Spacecraft Bus Description

Notes:
(1) The following have been removed for the BASIC Bus:
   - Imaging Sensor
   - Imaging Sensor Outer Barrel
   - Wideband Downlink and Gimbal

(2) Bay Covers removed to show interior equipment

5/11/99
LM900™ Design Features

- Commercial Remote Sensing Satellite (CRSS)
- Mission Life: 6 yrs, MMD 5 yr
- Aluminum Hexagon Structure
- Mass: 500 kg (1100 lbs)
- Reliability: > 0.9 reliability at 5 years

- Propulsion:
  Six Thrusters, 0.2 lbs each
  Monopropellant: 83 lbm(N₂H₄)
  Total Impulse: 16,700 lbf-sec
- Power
  Battery Ni H₂: 50 Amp-hrs
  Unregulated Bus Voltage: 28±6 Vdc
- Thermal Control
  Battery radiators
  Conduction cooled

- Zero Momentum, 3-Axis Stabilized
- Agility 4 deg/sec max rate
  0.2 deg/sec acceleration
- Precision Attitude Determination & Pointing
  Pointing Control ± 12 arcsec (1sig)
  Pointing Knowledge ± 10 arcsec (1 sig)
- Pointing Stability
  2.5 arcsec (< 1 Hz)
  0.8 arcsec (> 10 Hz)

5/11/99
LM-900™ Baseline Payload Capabilities

- **Payload Mass**
  - up to 500 kg

- **Payload Volume**
  - Internal Cylinder Vol: 78 cm dia x 101 cm
  - External Volume: 220 cm dia x 127 cm
  - Electronics Bay: 94 cm x 84 cm x 38 cm

- **Power**
  - Solar Arrays: 3 Fixed
    - 1200W BOL/ 1022W EOL peak power to payload orbit dependent

- **Wideband Communications**
  - S-Band @ 2 Kbps uplink
  - X-Band @ 32 Kbps downlink
  - CRSS Gimballed Antenna, X- Band @ 320 Mbits/sec downlink

- **Solid State Recorder**
  - up to 80 Gbit (BOL) EDAC
  - protected high-speed memory
An increased payload load capability is available on a mission-unique basis with minor booster adapter and bus modifications. For all payloads, a complete dynamics analysis of the integrated spacecraft must be completed to ensure compatibility of all components.

(The above is based on a quasi-static analysis of LM900™ on Athena-2 booster)
LM900™ Payload External Envelopes

92 in LMLV-2

92 in Taurus Orion 38 Configuration

5/11/99
Conclusion

- LMMS offers range of smallsat busses
ORBITING TECHNOLOGY TESTBED INITIATIVE (OTTI)

PROGRAM PRESENTATION

TO: RideShare Conference

JIM RITTER
SAIC
ART CAMPBELL
NRL
APRIL 15, 1999
THE NASA SPACE CHALLENGE:

- An Order of Magnitude Increase in Performance
- Significantly Lower Power Devices and Systems
- Lower Weight Spacecraft and Launch Vehicles
- Lower Cost Devices and Spacecraft
- Faster and Cheaper Assembly Times
- Reliable Systems Capable of Operation Anywhere in the Natural Space Environment

Faster, Cheaper and Better Space Systems!
THE COMMERCIAL SPACE CHALLENGE:

( The Goal of World-wide Voice, Data, Fax, Surveillance and Video Teleconferencing Requires:
  • Large Numbers of Spacecraft for Coverage
  • Higher Orbits Permit Use of Fewer Spacecraft, but Require Hardening
  • Large Investments in Both Space and Ground Systems

( International Competition Requires:
  • State-of-the-art Technology
  • Fast Time to Orbit, Mass-produced Spacecraft
  • Reliable Systems Capable of Operation in the Natural Space Environment

Faster, Cheaper and Better Space Systems!
HIGH PERFORMANCE COMMERCIAL DEVICES ARE OFTEN VERY SENSITIVE TO NATURAL SPACE RADIATION

- Device Vulnerability to SEE and Total Dose Increases as:
  - Feature Size Decreases (Capability Increases)
  - Speed Increases
  - Voltage and Power Decrease

- New Technologies Must Be Space Qualified Before Use in Operating Systems
HOW CAN NASA MEET THESE GOALS?

( ) Use Novel, Break Through Technologies
   • X 5-10 Increase in Performance
   • Potential New Capabilities

( ) Use COTS or Rad Tolerant COTS Parts Rather than Rad Hard Parts
   • X 10 More Capable (2-3 Generations Ahead of Rad Hard)
   • Less Expensive, More Available

( ) Partner With and Leverage Commercial Space and Industry
   • Fly Technologies of Interest to COMSATS
   • Industry Pays for Its Payloads
   • Make Use of Commercial Spacecraft and Launch Vehicles to Further Reduce NASA’s Costs
THE OTTI PROGRAM WILL:

- Demonstrate and Space Qualify Break Through Technologies and COTS Systems
- Partner With the Commercial Satellite Industry, Fly Their Payloads and Use Their Spacecraft and Launch Vehicles, If Possible
- Operate in a GTO or MEO High Radiation Orbit
- Compare Ground Tests to Space Tests
- Develop New Models With Reduced Uncertainty (Lower Safety Factors Required = Reduced System Costs)
PURPOSE - SUMMARY

PURPOSE: OTTI is a Program to: (1) Explore Novel, Emerging Breakthrough Technologies and Advanced SOA Devices and Adaptive Subsystems With Substantial Potential Impact on Space System Performance and to: (2) Decrease the Time and Cost Required for Insertion Into Future NASA Systems by Space Demonstrations and by Leveraging Commercial Space Systems

SUMMARY:
- Explore, Assess and Test Potential Breakthru Technologies
- Select Most Promising Technologies and Plan Space Expt.
- Construct Payloads and/or spacecraft
- Predict Space Performance Using Best Models, Ground Tests
- Launch Experiment and Analyze Space Data
- Compare Space Data to Predictions and Develop New Models
- Leverage Commercial Space Systems to Reduce Costs
THE OTTI TEAM:

- NASA HQ
- NASA GSFC
- JPL
- NASA MSFC
- NASA GRC
- NASA LaRC
- NASA JSC
- SAIC
- NRL
- AFRL
- DSWA
- UNM
- SANDIA
ORBITS CONSIDERED FOR OTTI

1. Circular MEO, Equatorial 3,000 km
2. GTO, 36,000 km, 18 Degrees
3. Circular MEO, Polar, 3,000 km
4. Elliptical MEO, Polar, 1,000 x 6,000 km

GTO Recommended for Maximum Coverage of Radiation Issues
INITIAL EXPERIMENT LIST

Devices
1. Low Power CMOS (0.3 V)
2. Magnetic Thin Film Non-volatile Memories
3. Advanced Cots Devices
4. LT GaAs Devices
5. InP Devices
6. SiGe Devices
7. InAs Devices
8. Vertical-Cavity Surface Emitting Lasers
9. Reconfigurable Processing
10. COTS In Multichip Module Packaging
11. Solar Cell Experiments
12. MEMs
13. Erasable Hard Disc Memory

Subsystems
14. IR, UV and Visible Sensors
15. P-channel CCDs and CMOS Active Pixel Image Sensors
16. 32 Gbps VCSEL Based Optical Bus
17. Fiber Optic Data Bus
18. Star Tracker, Sun and Earth Sensors
19. Artificial Neural Nets
20. Fuzzy Logic Circuits
21. System on a Chip
22. GPS Receiver
23. Direct Intra-board IR Communication

Environmental Instruments
24. Proton Spectrometer
25. Dosimeters
26. Credo III-Or IV
27. Cease
POTENTIAL LAUNCH PARTNERSHIPS* (Commercial Communications Satellite Industry)

Launch, Spacecraft Acquisition Possibilities

- Orbital Science - CEO
  - Up to 50kg, 200 W (Max.) Payload on Each Satellite (12)
  - 1965 km, 0 Degrees

- DRG - LEO 1
  - Up to 120 Lb., 100 W Payload
  - 950 km, 50 Degrees or 950-4000 km, 50 Degrees, Elliptical
  - 165 kg, 200 W Satellite

- Motorola - Iridium (INX)

- Teledesic - 1400 km

- Lockheed Martin

- Spectrum Astro
  - SA 200B Bus, 3 Axis Stabilized, Available on IDIQ

* In Exploratory Stage
PAYOFFS: - OTTI WILL PROVIDE PATTERN FOR NASA AND COMMERCIAL COMMUNICATION SATELLITE INDUSTRY PARTNERSHIP

( NASA Could Take Advantage of Industry’s Mass Produced Spacecraft and Frequent Launches by Using the OTTI Example, Modifying Commercial Space Hardware and Launching Jointly

( Industry Could Launch NASA Payloads on Its Satellites With Cost Sharing

( NASA Could Launch Industry Payloads on Its Testbed With Cost Sharing
OTTI PAYLOAD*

( High radiation orbit required - elliptical GTO or MEO
  - Elliptical GTO preferred for radiation variety
    ▶ trapped electrons and protons as well as cosmic ray ions and solar
    event particles are important to experiment
  - MEO in proton belts acceptable <1400 km

( Weight - 75 kg

( Size - 100x80x30.5 cm (expect multi-package, auxiliary experiments)

( Power - 150 watts (can easily power share but must maintain biases)

* In Exploratory Stage
Quick Ride: An Innovative Approach For Low Cost, Quick Access Small Payload Missions

RideShare Conference

April 15, 1999
Contents

- Background
- Flight Opportunities
- Range of Accommodations
- Optional Services
- Program Plan
- Cost Summary
- Summary
Background

A Privately-Owned Commercial Space Company Since 1992

Aerospace Engineering Services  SatSystems Development  Secondary Payload Program  Mobile Satellite Systems
Background

- 4-5 year history of promoting secondary payloads
- Incorporated payload accommodation in satellite design
- Responded to NASA's QUICK RIDE announcement
- QUICK RIDE provides:
  - Launch
  - Satellite control center (Lanham, Maryland)
  - Operations
  - Payload data available via dedicated line/web
Constellation & Satellite

Constellation

Satellite
**Manifest**

<table>
<thead>
<tr>
<th>Contract Line Number</th>
<th>Planned Manifest Date:</th>
<th>9/01</th>
<th>3/02</th>
<th>9/02</th>
<th>3/03</th>
<th>9/03</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Rides on Manifest Date:**</td>
<td></td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
</tbody>
</table>

**All missions will have an orbit altitude of 1000km, an orbit inclination of either 51° or 66°, and an eccentricity of 0.0±0.01.**
# Accommodations Summary

<table>
<thead>
<tr>
<th>Performance Characteristic</th>
<th>Quick Ride Minimum</th>
<th>Standard Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument Mass</td>
<td>10 Kg</td>
<td>≤ 20 Kg</td>
</tr>
<tr>
<td>Instrument Power</td>
<td>10 watts</td>
<td>&lt; 20 watts Cont.</td>
</tr>
<tr>
<td>Instrument Volume</td>
<td>50,000 cc</td>
<td>≤ 100,000 cc</td>
</tr>
<tr>
<td>Thermal Control</td>
<td>Isolated</td>
<td>Isolated</td>
</tr>
<tr>
<td>Data Storage</td>
<td>100 Mbits</td>
<td>≤ 128 Mbits</td>
</tr>
<tr>
<td>Downlink Data</td>
<td>2 Mbits/day</td>
<td>4 Mbits/day</td>
</tr>
<tr>
<td>Data Rate (onboard)</td>
<td>1 Kb/sec</td>
<td>≥19.2 Kb/sec</td>
</tr>
<tr>
<td>Command Uplink</td>
<td>200 bits/sec</td>
<td>≥9.6 Kb/sec</td>
</tr>
<tr>
<td>Ordering Period</td>
<td>Prior to L-18 months</td>
<td>Prior to L-18 months</td>
</tr>
<tr>
<td>Instrument Delivery</td>
<td>L-9 months</td>
<td>L-9 to L-6 months</td>
</tr>
<tr>
<td>In-orbit Operations</td>
<td>12 months</td>
<td>12 months</td>
</tr>
</tbody>
</table>
Optional Ground Software

- Additional telemetry points in database
- Additional commands in database
- Additional operations tools, rules, or other products, such as displays, procedures, or state models
- Adding ancillary data onboard
- Adding more complicated commanding or data collection pass scheduling requirements
- Additional ground processing of data collected
# Program Plan

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 Month Requirements Analysis to perform trade-offs to determine standard or optional services</td>
</tr>
<tr>
<td>2</td>
<td>3 Month Payload Interface Design, Operations Planning and I&amp;T Planning leading to a Mission Design Review</td>
</tr>
<tr>
<td>3</td>
<td>6 Month Operations and Interface Development unique space and ground interfaces are built.</td>
</tr>
<tr>
<td>4</td>
<td>6 Month integration of payload into the satellite including environmental testing</td>
</tr>
<tr>
<td>5</td>
<td>2-3 Month launch schedule</td>
</tr>
</tbody>
</table>
Integration & Test

Payload integration at Lanham, Maryland

Controlled Access

Clean Rooms (Class 10,000)

Integration performed by Final Analysis technicians according to the Integration Plan

All handling devices are calibrated

Strict static discharge control procedures are followed

Observation by experiment team member (s)

Note: USG will furnish instruments, Flight software and instrument I&T software
## Cost Summary

### Quick Ride Flights with 12 Months of Operations.

<table>
<thead>
<tr>
<th>Flight Number</th>
<th>Price per Flt (FY 99 $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$2.6 Million</td>
</tr>
<tr>
<td>2 through 10</td>
<td>$2.5 Million</td>
</tr>
</tbody>
</table>

### Accommodation Studies

<table>
<thead>
<tr>
<th>Flight Number</th>
<th>Price per Flt (FY 99 $)</th>
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</thead>
<tbody>
<tr>
<td>1 through 10</td>
<td>$115K</td>
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</table>

### Mission Unique Modification

<table>
<thead>
<tr>
<th>Flight Number</th>
<th>Price per Flt (FY 99 $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 through 10</td>
<td>Priced per Task Order</td>
</tr>
</tbody>
</table>

Additional Optional Capabilities of Quick Ride:
- High Rate Downlink
- 256 MB Onboard Storage
- Improved Attitude Knowledge
Summary

Customer provides documentation, procedures, test results, drawings etc... to enable Final Analysis to perform analyses, develop the interface, integrate and test the satellite with the Quick Ride payload.

Quick Ride offers low cost access to space.

Program depends upon NASA and industry cooperation.

FAI is ready to cooperate to the fullest extent possible! -> Mission Success
Prepared by:
Jason O'Neil
Business Development
Final Analysis Inc.
9701-E Philadelphia Court
Lanham, Maryland 20706-4400
301-459-4100
jason@finalanalysis.com
• Naval Space S&T Program Office Overview

• Navy Payloads

• GEO Mission

• Enabling Technologies

• Summary
RADM Gaffney (CNR) Chartered the Naval Space Science and Technology (S&T) Program Office.

**Focus:**
- Central Point of Contact for DON S&T Activities
- Horizontal Linkage and S&T Transition With External Commands, PEO's, and Agencies
- Investment Strategy to Leverage DOD, Government and Commercial Initiatives
- ONR Program Officers Manage ONR Space Programs and Other DON Space Organizations Programs

**Mission**

*Keep the Navy "SMART"*

Support The Warfighter
Maximize Leverage of Navy Dollars
Acquire Partners
Rapid Technology Transition
Technological Superiority

**Requirements**
- S&T Round Table Process
- S&T Requirements
- Guidance (STRG)
- NASA
- DoD
- NRO
- Industry
- Academia

Invest Uniquely In Cutting Edge

Naval Space S&T Investment Plan
### Naval Space S&T Program Investments

<table>
<thead>
<tr>
<th>FY98</th>
<th>FY99</th>
<th>FY00</th>
<th>FY01</th>
</tr>
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<tbody>
<tr>
<td><strong>Communication</strong></td>
<td></td>
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<tr>
<td>Modulating Retro Reflector</td>
<td>GPS Anti-Jamming</td>
<td>GPS Anti-Jamming</td>
<td>Geo Ionospheric Imager</td>
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<tr>
<td>Geo Ionospheric Imager</td>
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<td>Geo Ionospheric Imager</td>
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<tr>
<td><strong>Navigation</strong></td>
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<tr>
<td>Geo Ionospheric Imager</td>
<td>GPS Anti-Jamming</td>
<td>GPS Anti-Jamming</td>
<td>Geo Ionospheric Imager</td>
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<tr>
<td>Satellite Laser Ranging</td>
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<td>Geo Ionospheric Imager</td>
<td></td>
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<tr>
<td><strong>Environmental Sensing</strong></td>
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<td>WindSat</td>
<td>WindSat</td>
<td>WindSat</td>
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<tr>
<td>NEMO</td>
<td>NEMO</td>
<td>NEMO</td>
<td>GEO Program Definition</td>
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<tr>
<td>HRST Aerosol Parameters</td>
<td>HRST Aerosol Parameters</td>
<td>HRST Aerosol Parameters</td>
<td>SMI</td>
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<tr>
<td>Aerosols &amp; Atmos. Parameters</td>
<td>Aerosols &amp; Atmos. Parameters</td>
<td>ASIS Buoy Experiment</td>
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<tr>
<td>Wind Vector Modeling</td>
<td>Wind Vector Modeling</td>
<td>Wind Vector Modeling</td>
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<tr>
<td>Active/Passive Microwave Freq.</td>
<td>Active/Passive Microwave Freq.</td>
<td>GEO Bus Concept Study</td>
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<tr>
<td>Polarimetric RS of Ocean Surface</td>
<td>Polarimetric RS of Ocean Surface</td>
<td>(SMI)</td>
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<tr>
<td>Passive Microwave Radiometry</td>
<td>Passive Microwave Radiometry</td>
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<tr>
<td>GEO Sensor Concept Study (SMI)</td>
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<tr>
<td><strong>Surveillance</strong></td>
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<td>Sparse Aperture</td>
<td>Sparse Aperture</td>
<td>Sparse Aperture</td>
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<td>IOBP</td>
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<td>IOBP</td>
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<tr>
<td><strong>Technology Transition Path or Demos</strong></td>
<td>Modulating Retro Reflector</td>
<td>NRL 6.2 New Start</td>
<td>Base Program</td>
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<tr>
<td>Modulating Retro Reflector</td>
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<td>Flight Demo</td>
<td>Flight Demo</td>
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<tr>
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<td>Flight Demo</td>
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<tr>
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<td>Flight Demo</td>
<td>LEO Fizeau Demo Program (FY00-04) NRL/NRO</td>
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<tr>
<td>Sparse Aperture</td>
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<td>Flight Opp. FY02</td>
<td>Flight Demo</td>
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<tr>
<td>Geo Ionospheric Imager</td>
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<td>METOC Start FY02</td>
<td>Flight Demo</td>
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<tr>
<td>METOC GEO Program</td>
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<td>Flight Demo</td>
<td></td>
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<tr>
<td>GPS A/J</td>
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<td>Flight Demo</td>
<td>Flight Demo</td>
</tr>
</tbody>
</table>
• Naval Space S&T Program Office Overview

• Navy Payloads

• GEO Mission

• Enabling Technologies

• Summary
Remote Atmospheric & Ionospheric Detection System (RAIDS)

8 Instruments (Spectrometers & Photometers)
Wavelength Coverage: 550 - 8700 Å @ 7-20 Å
Scans the Limb: 50 - 750 km @ 5 km Resolution
Expected Launch: 2001
Tactical Ionospheric Remote Sensing from Geostationary Orbit

**Ionospheric Mapping & Geocoronal Experiment (IMAGE)**

- High Time & Space Resolution Ionospheric Imaging
  - Precision Geolocation of Emitters
  - Improved GPS Accuracy
  - Satellite Altimetry (GFO)
  - Theater Ballistic Missile Defense
- Real-Time Tracking of Ionospheric Irregularities & Scintillation Regions
  - Reduced Communication & Navigation Outages (UHF, HF, GPS)
- Possible Piggyback for Indian Ocean Geostationary Satellite
  - Space Flight Support from Space Test Program
  - Synergistic with USAF C/NOFS ACTD

![Apollo 17 Ultraviolet Image of the Earth](image)

---

**ABC Multiple Diagnostic Campaign**

**Scintillation Region**

**All-sky Images**
MISSION OBJECTIVE: Support Navy unique, space-based METOC requirements
Development, calibration and validation of new sensors
Support delivery of satellite products to the fleet, and risk-reduction efforts for inter-agency (DoC/DOD) converged satellite programs (NPOESS)
Support Navy participation in cooperative efforts (DMSP)

APPROACH:
Space-based Sensor Development
Calibration and Validation Cooperative Efforts
Advanced Sensors for Ground Based Validation
Post-Launch Operational Product Support

Supplemental METOC Imager
High Priority CINC Requirement: High Resolution Visual & IR Imagery of the Indian Ocean

**METOC Imagery Requirements**
- Clouds and fog
- Cloud drift winds
- Cloud Top Height
- Secondary Requirements
  - Cloud heights
  - Water Vapor Winds

**Sensor Requirements for Primary Parameters**
- Vis 0.55 - 0.75 μ
- IR 7.1 - 13.6 μ
- 10 or 12 bit precision
- 100 kg, 0.75 m³, 100W

**Space/Time Requirements**
- Hi-resolution (1 km day/4 km night)
- 2 hour refresh, full disk
- ≤30 minute refresh, sector
- 3 km geolocation

**Current Activities:**
- Raytheon Study Completed
- Lincoln Lab System Study In Process
- Non-Acquisition Program Definition Document (NAPDD) being Developed for Summer FY99 Submission
- Satellite/Launch Vehicle Options Being Explored

**Sponsors:** CNO(N6) and CNO(N096)

**Program Management:** ONR 32SO (Space Office)

**Conceptual Approach:**
National/DoD/Industry Partner for Satellite and Launch Industry Partner for Sensor
SMI Sensor Concept

- 30 cm aperture off axis telescope or 2-axis gimbal
  - Compact package minimizes impact on spacecraft
  - Off axis three mirror design provides superior imaging and minimizes solar intrusion effects
- Two area arrays, one each for the visible and IR
  - 1280 x 1280 CCD array
  - 320 x 240 uncooled IR array
  - Filter wheel enables IR band selection
- Projected mass: 82 kg
- Projected volume: 0.5 m³
- Projected power: 80 W (avg), 120 W (peak)
Projected SMI Capabilities

- Provide visible and infrared images
- 1 km resolution in one visible band
- 0.55 to 0.75 μm
- 7.1 to 7.5 μm
- 10.2 to 11.2 μm
- 13.1 to 13.6 μm
- 42 min full disk revisit for 1500 km x 1500 km region
- Data rate ~450 kbps to meet Navy's reporting requirements and is compatible with AN/SMQ-11 system

Environmental data performance similar to GOES for mission parameters

Santa Barbara Remote Sensing
Naval Space S&T Program Office Overview

Navy Payloads

GEO Mission

Enabling Technologies

Summary
Supplemental Metoc Imager (SMI) Proposed Partnership

**NAVY:**
Maximize Leverage of Dollars
Acquire Partners
Technology Transition

**Total S/C & Launch:** $90M

1/3 Cost
SMI
Enabling Technologies

**NASA**
Experiments
Sensor(s)
Technologies

1/3 Cost

**INDUSTRY Partner or Other GOV'T**
Experiments
Sensor(s)
Technologies

1/3 Cost
• Naval Space S&T Program Office Overview

• Navy Payloads

• GEO Mission

– Enabling Technologies

• Summary
• Navy Has Defined GEO Requirements
  – Looking for Partner(s)
    • Government and/or Industry

• Emerging Technologies Can Enable More Capable GEO Bus
  – Cost Effective Frequent GEO Missions

• Call me... 703-588-0702
Student Micro/Nano Space Applications

RideShare Conference
Litton/TASC
Chantilly, VA
April 15-16, 1999

Prof. Robert J. Twiggs
Department of Aeronautics & Astronautics
Stanford University
Stanford, CA
University Space Projects

- Weber State University
  - Started 1982  NUSAT - 1985  AMSAT/Microsats - 1990
- University of Alabama- Huntsville
  - Started ~ 1988  Sedsat - 1999
- Arizona State University
  - Started ~ 1993  ASUSat1 - OSP Launch 1999
- Naval Postgraduate School
  - Started ~ 1986  Shuttle Launched 1999
- Stanford University
  - Started 1994  Sapphire - Ready to launch (no Launch)
    - OPAL - OSP Launch 1999
- Nanosat Program
  - Started 1999  Ten Nanosats Launch 2001
Space Programs for Education

- Educational Goals & Challenges
  - Provides Project Life-Cycle Experience
  - Student Managed
  - Student Run

VERY UNSTRUCTURED
Projects

• Microsatellite Design Program - MS Level
  ➢ SQUIRT Class - 20 kg

• Advanced Spacecraft Development - Ph.D.
  ➢ 40 - 100 Kg
  ➢ SHARP - Atmospheric Reentry Vehicle for Thermal Systems Protection Tests

• Spacecraft Operations Research - Ph.D.
  ➢ ASSET - Autonomous Space Systems Experimental Testbed

• Other - Undergraduate
  ➢ Ares
  ➢ CanSat
  ➢ Barnacle
# Project Cost Range

<table>
<thead>
<tr>
<th>Graduate</th>
<th>Material Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQUIRT - &lt;20 kg nano/micro satellite ------ MS Degree Project</td>
<td>&lt;$50,000</td>
</tr>
<tr>
<td>Advanced Programs - &lt; 50 kg</td>
<td></td>
</tr>
<tr>
<td>Orion - formation flying - Engr/Ph.D. Project</td>
<td>~$150,000 - $250,000</td>
</tr>
<tr>
<td>SHARP - hypersonic reentry vehicle test bed - Engr/Ph.D. Project</td>
<td>~$250,000</td>
</tr>
</tbody>
</table>

| Undergraduate/Pre College        |               |
| Picosats - payloads for microsatellites - Santa Clara University | ~$1,000        |
| Ares - remote data collection - Antarctic -> Mars               | ~$5,000        |
| CanSat - new challenge - University of Tokyo, Tokyo Institute of Technology, | ~$1,000        |
| Stanford University, University of Texas - Austin             |               |
SAPPHIRE - Microsatellite

Payloads

MEMS Infrared Sensor
Voice Synthesizer
B/W Digital Camera
Passive Magnet Stabilized

18" Diameter
12" Height
22 kg Weight

Stanford's First Student Built Microsatellite
Ready to Launch July 1998
OPAL - Microsatellite

Picosat Launcher

Mother - Daughter Spacecraft

50 m Diameter Astronomy Antenna
For Picosat Communications

Stanford's Second Student Built Microsatellite
Scheduled Launch September 15, 1999

Low-cost Testing of New Technologies

RideShare Conference - April 15-16, 1999

Stanford University
JAWSAT/OSP Launch

OSP Vehicle With JAWSAT

JAWSAT with OPAL
Artemis 4-inch Picosatellite

- Transmitter beacon
- Transmits Artemis website address
Artemis 8-inch Picosatellites

- Study VLF emissions from thunder clouds
- Record 15 seconds of simultaneous data at 11 kHz
- Compare two data sets to approximate ionospheric aberrations
Stensat Picosatellite

- single channel mode "J" FM voice repeater
- uplink at 145.84 MHz downlink at 436.625 MHz
- periodically transmits telemetry
- amateur radio operators able to "PING" the satellite causing it to broadcast a telemetry packet
Picosatellite Stack

Ejection from OPAL
Two tethered picosatellites

Testing DARPA MEMS RF switches

Testing of inter-satellite communications link and protocol
Emerald - Nanosatellite

Advancing Formation Flying with Student Built Nanosatellites

Stanford’s Third Student Built Microsatellites
Scheduled Launch Early 2002
Orion - Formation Flying

Vision - Distributed, highly coordinated satellites perform a unified mission

Advantages - Large baselines, graceful degradation, flexible deployment

The Stanford Orion Project
Sub-meter relative position control
3-6 spacecraft formation
40 kg, 3-axis control, cold gas thrusters

Stanford's First Advanced Microsatellites
Scheduled Launch Early 2002
Ares Mars Project

Mars Imaging with Weather Probe

- Undergraduate project
- Camera in nose of probe
- Collect imaging data on descent
- Store images
- Transmit through Mars orbiter to earth
- Need space test before Mars
Barnacle Project

Parasat class

- Undergraduate project
- Permanently attached to last stage of ELV
- Battery operated
- Comm system with uplink and downlink
- Short life testing
- Any orbit
ESPA

Secondary Launches

primary spacecraft

standard Ø 62.01" interface

small secondary spacecraft

large secondary spacecraft

ESPA

RideShare Conference - April 15-16, 1999
ESPA

Nanosat Program Secondary Launches
Conclusions

Need for Secondary Launches

• Many university programs
• Many projects
• Excellent drivers for student education
• Trained engineers for industry and government labs

Projects for Really GOOD GOOD Education
United Space Alliance

Products and Services for Space Operations
- Space Hardware Processing
- On-Orbit Operations
- Launch & Return Operations
- Space Systems Training

NASA’s single prime contractor for Shuttle operations
"Reimbursable Missions"

- Two Flight opportunities on OV-102, Columbia
  - "marketing of payloads ... positive step toward our goal of privatizing/commercializing"
  - flight opportunities shown on manifest are 6/02 and 7/03
    - these are place-holder dates; actual dates will be defined by primary payload launch requirements
- USA to lease Shuttle payload bay
  - payload customers charged pro-rated amount based on use of Shuttle resources
"Reimbursable Missions"

- Services provided by USA
  - manifest payload
  - single point of contact for payload
  - interface with NASA on behalf of payload
  - arrange/provide upper stage and/or carriers/cradles, if necessary
  - payload integration
  - on-orbit support
"Reimbursable Missions"

- United Space Alliance offers turnkey solutions to getting your payload into space

To learn more about flight opportunities:

*Therese Thrift*

Director, Strategic Business Planning

281.280.6958
Provide an overview of SPACEHAB and its ability to "fly" payloads for the NRO.

- Company Overview
- Overall Capabilities
- Integration Process
- Contractual Arrangements
- Summary
SPACEHAB, Inc.
- The leading commercial space services company supporting both manned and unmanned missions to space
- First company to develop, own and operate habitable modules that provide space-based laboratory research facilities and cargo re-supply services aboard the U.S. Space Shuttle fleet

ASTROTECH
- Offers customers a commercial alternative to the Government payload processing facilities at the Kennedy Space Center, with the full cooperation of NASA
- Provides Payload Processing for Civil and Commercial Satellites
- Leading commercial provider of launch processing services in the United States

Johnson Engineering
- A highly diversified enterprise primarily engaged in design, development, fabrication and integration of technology products and services
- The company’s core businesses include design engineering for electrical, mechanical, and software systems, aquatic/ocean engineering, fabrication, space systems, and systems integration
Business Model
- Identify undefined requirements
- Create products & services to satisfy requirements
- Invest private capital to build assets
- Price according to value assessment
- Determine project viability at this price

Missions
- Twelve successful missions on two NASA contracts - Space Shuttle research and cargo resupply to Mir space station
- Over 100 experiments flown in Module, Middeck, and on roof top
- Additional Shuttle research and ISS cargo resupply missions under REALMS contract
SPACEHAB has relationships with an international alliance of space-related organizations.
SPACEHAB can arrange for flights on these carriers.

Duration of Weightlessness

- Parabolic Aircraft: <30 seconds
- Sounding Rockets: tens of minutes
- Space Shuttle: <16 days
- International Space Station: 90+ days

NOVESPACE - A300
DASA - Texus, MAXUS
SMART Can (GAS)
SPACEHAB
SPACEHAB - Module, Pallets
SPACEHAB - Wake Shield

Chris Martin • 202-488-3500
Modules for Various Missions

- Single Module
  - Modules for Shuttle research, Station resupply and reboost
  - Module used varies by need
  - All can carry active research

- Double Module Exterior

- Logistics Double Module

- Research Double Module

- Docking Double Module

Research  Station Cargo
Current Capabilities

Module missions include:
- Middeck lockers
- SPACEHAB lockers & racks
- Station ISPRs
- Exposed rooftop payloads
- Fabric transfer cargo bags
- Oversized cargo items

Payload resources include:
- AC and DC power
- Air and water cooling
- Crew time support
- Downlink data and video
- Uplink commanding
- Vacuum venting

- 9-15 month integration
- Off-site integration facility
- Many payloads refloated from Middeck, Spacelab
➢ Flown several times in logistics and science support roles
➢ Provides 4800 pounds of payloads with full resources
➢ Maximizes Shuttle co-payload volume

➢ Lockers flown on both bulkheads
➢ Can house 2 ISPR or SPACEHAB racks
➢ 2 external rooftop locations at 500 pounds
Research Double Module

- Design started in August 1996; first flight on STS-107
- Provides 9000 pounds net payload with full resources
- Shuttle-independent data services

- Lockers flown on both bulkheads
- Can house 6 racks or 4 ISPR's
- 4 external rooftop locations at 500 pounds

Double Module Exterior

Forward

Expanded View

Aft

Chris Martin • 202-488-3500
### Payload Resources

<table>
<thead>
<tr>
<th></th>
<th>Single Module</th>
<th>Research Double Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight (lb) [kg]</strong></td>
<td>4800 (2177)</td>
<td>9000 (4081)</td>
</tr>
<tr>
<td><strong>Power - on orbit</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC (W)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC (VA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Exchanger - on orbit (W)</td>
<td>4000</td>
<td>5500</td>
</tr>
<tr>
<td><strong>Vacuum Venting</strong></td>
<td>1 Experiment Vent Valve (EVV)</td>
<td>1 EVV forward 1 EVV aft</td>
</tr>
<tr>
<td><strong>Data Transfer (NASA)</strong></td>
<td>low rate PDI (discrete, analog, serial, 25 kbps total)</td>
<td>low rate PDI (discrete, analog, serial, 25 kbps total)</td>
</tr>
<tr>
<td></td>
<td>RS-232 via Serial Converter Units</td>
<td>KuSP channel1/2 (2 Mbps total)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KuSP channel3 (48 Mbps total)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ethernet standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>other interfaces by plug-in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hardware &amp; software (RAU, 1553)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- on orbit record/downlink of LOS data</td>
</tr>
<tr>
<td></td>
<td>64-256 kbps up/downlink via SHUCS system</td>
<td>64-256 kbps up/downlink via SHUCS system</td>
</tr>
<tr>
<td><strong>Video Downlink</strong></td>
<td>Video Switch Unit</td>
<td>Video Switch Unit</td>
</tr>
<tr>
<td></td>
<td>- 8 module inputs</td>
<td>- 8 module inputs</td>
</tr>
<tr>
<td></td>
<td>- camcorder power</td>
<td>- camcorder power</td>
</tr>
<tr>
<td></td>
<td>- onboard monitors</td>
<td>- onboard monitors</td>
</tr>
<tr>
<td></td>
<td>- output to Orbiter CCTV PL input</td>
<td>- output to Orbiter CCTV PL input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>selectable outputs to video</td>
</tr>
<tr>
<td></td>
<td></td>
<td>digitizer</td>
</tr>
<tr>
<td><strong>Commanding Uplink</strong></td>
<td>low rate PSP (2 kbps max.)</td>
<td>low rate PSP (2 kbps max.)</td>
</tr>
<tr>
<td></td>
<td>42 - 62</td>
<td>high rate KuSP channel1 (28 kbps)</td>
</tr>
<tr>
<td><strong>Locker Capability (lbs)</strong></td>
<td>27 - 61</td>
<td></td>
</tr>
<tr>
<td><strong>Rack Capability (racks)</strong></td>
<td>2 SH double or single racks</td>
<td>6 SH double or single racks</td>
</tr>
<tr>
<td></td>
<td>1 SPAR may sub for a SPACEHAB rack with adapter</td>
<td>- 4 SPAR's may sub for SPACEHAB racks with adapter</td>
</tr>
<tr>
<td><strong>Refrigerator/Freezer (OSRF)</strong></td>
<td>-20 to 40°C, payload of up to 1.85 ft³, 40 lb</td>
<td>-20 to 40°C, payload of up to 1.85 ft³, 40 lb</td>
</tr>
<tr>
<td><strong>Viewports (units)</strong></td>
<td>0 - 2</td>
<td>0 - 2</td>
</tr>
</tbody>
</table>

- **Chris Martin** • **202-488-3500**
- **Commercial Space Hardware Capabilities • 4/99**
payload accommodations

**Lockers**

**Single & Double Racks**

**ISPRs**

**Viewports**

*External payloads possible. Floor mounting in-work (500 lb.)*

<table>
<thead>
<tr>
<th></th>
<th>Locker 1, 3</th>
<th>Single Rack</th>
<th>Double Rack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (lbm) [kg]</td>
<td>60 [27]</td>
<td>655 [297]</td>
<td>1250 [567]</td>
</tr>
<tr>
<td>Volume (cu. ft.) [liter]</td>
<td>2 [56]</td>
<td>26 [740]</td>
<td>53 [1500]</td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC (VA)</td>
<td>allocable</td>
<td>allocable</td>
<td>allocable</td>
</tr>
<tr>
<td>Ascent, Descent (W)</td>
<td>115</td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>DC (W)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Rejection (W)</td>
<td>air cooling</td>
<td>suction air, water cooling interfaces</td>
<td></td>
</tr>
<tr>
<td>Vacuum Venting</td>
<td>available throughout module</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crew Time (hr)</td>
<td>14</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td>Data, Commanding</td>
<td>downlink: analog, discrete, serial, low-rate data, high-rate digital downlink &amp; recording CCTV, NTSC video</td>
<td>uplink: serial, pulse discrete commanding</td>
<td></td>
</tr>
</tbody>
</table>

1 Accommodation in Shuttle Middeck locker(s) possible with similar capabilities.
2 Not payload mass; mass of lockers and racks not included.
3 Resources for Soft Stowage®, plates, and panels same as locker plus mass delta.
4 General allocation; exact value dependent on mission and number of crew shifts.
5 Exact value is mission-dependent; RDm high power location provides 3 kW.
6 Soft Stowage® and Soft Rack® are registered trademarks of the McDonnell Douglas Corporation, a wholly-owned subsidiary of the Boeing Company.
Mounts to either forward or aft SPACEHAB module bulkhead

Provides dimensionally-identical interior interface for Middeck payloads

Provides three removable front door panels for use as is, modification, or deletion

Payload support capabilities:
- 2 ft³ (56 liters)
- 60 pounds (27 kg)
- 115 W DC power on-orbit
- Ascent and descent power
- Air cooling (normally)
- Various data services
- Late and early access of contents
External Payloads

- Full payload support capabilities:
  - 500 pounds at several rooftop locations
  - 12,000 pounds on pallet
  - Crew operation
  - DC power
  - Downlink data, uplink commanding
  - Active cooling can be developed

- Total capability levels can be driven by customer requirements
Unpressurized Cargo Pallet

- First pallets nearly complete by DASA and RSC-Energia
- First use - STS-96 (May '99)
- Consists of Keel Yoke and Pallet
- Design features:
  - 12,000 lb. payload capability
  - Cargo mounts to top and bottom of pallet
  - Standard EVA site support
- Can be manifested
  - with SH module
  - over tunnel
  - alone
  - with MPLM
- Future upgrades provide for
  - standard transport container service
  - active payload support
  - long-term ISS deployment
Use of QUEST allows:
- Standardized external (attached) payload structural interface
- Power, data, and thermal interfaces (Space Shuttle only)
- Payloads to attach in a variety of Shuttle and Station carriers and facilities
Universal Communications System

➢ Payload data needs sometimes exceed Shuttle capabilities

➢ SHUCS provides payload-dedicated
  • audio over “phone”
  • low-rate video
  • data & commands via Internet or direct phone line
  • use of standard commercial hardware and software

➢ Using SHUCS
  • frees up Shuttle data systems for other co-payloads
  • allows research to continue when crew and Shuttle are unavailable

➢ Signals sent from module via Inmarsat to ground station and on to customer via phone line or Internet

➢ New Internet extension of .orb
Wake Shield Facility

- Provides free flyer and Space Shuttle bay payload flight opportunities
  - High atomic oxygen on free flyer ram side
  - High quality vacuum in free flyer wake
  - Molecular beam epitaxy thin film growth
  - Smart (GAS) cans on base carrier

- Resources provided:
  - Independent attitude control (free-flyer)
  - Downlink data, video; uplink commands
  - DC power
  - Environmental monitoring
  - High quality vacuum (free flyer wake)

- Commercial integration processes:
  - minimize personnel assignment time
  - minimize documentation required
  - maximize pre-flight time with hardware

- Three flights have proven hardware
Experienced SPACEHAB team provides a customer-friendly integration process that will be tailored to every customer’s individual needs.

**Characteristics:**
- **Single Interface:** SPACEHAB provides one point-of-contact for the complete integration process and shields customers from need for detailed knowledge of carrier integration processes.1 capability.
- **Streamlined Documentation:** Information is reused from previous use or other carrier if available.
- **Late/Early Access:** Significant experiment late access and early retrieval capability.
- **Launch Pad Installation:** Late module turnover to NASA allows more time with experiment hardware.
- **Flexible Approach:** Flight-ready payloads have been added as late as 45 days before launch.
- **Rapid Reflight:** SPACEHAB reflight payloads (same hardware and customer) start at L-8 months.
- **Quick Turnaround:** Short mission cycle supports commercial experiments.
- **Detailed Schedule:** Complete mission integration schedules are available at any time for customer use.
SPACEHAB Payload Processing Facility (SPPF):

- Located on a commercial site just south of KSC
- 44,500 square feet of payload integration, test, training, & support facilities with more square feet planned
- 11 industrially-secure Customer Work Areas (CWA’s) with three more rooms planned
- Clean room conditions - 100K class conditions in CWA’s, integration hall, shipping & receiving
- Integration hall accommodates flight modules and training units
- General - conference room, copiers, and fax machine available with new office areas planned

Off-site facility allows streamlined ground safety documentation, payload quality assurance, and international access processes.
Space is available today on STS-107, for flight in late 2000

- Process for spaceflight of COTS hardware is understood
- SPACEHAB ground and flight services
  - priced for STS-107 at $29,500 per kilogram for internal payloads
  - available through fixed price contracts (no US government involvement)
  - price includes all aspects of capabilities and integration services described in this presentation

- Optional services
  - Assistance with payload hardware adaptation for spaceflight
  - Assistance with payload safety and verification documentation

- Pricing for optional services can be made available on request

- Flight schedule:

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>STS-95</td>
<td>ISS-2A.1</td>
<td>ISS-2A.2</td>
<td>ISS-6A.1</td>
<td>ISS LON</td>
<td>STS-116</td>
</tr>
<tr>
<td>1999</td>
<td>STS-96</td>
<td>ISS-2A.1</td>
<td>ISS-2A.2</td>
<td>ISS-6A.1</td>
<td>ISS LON</td>
<td>STS-122</td>
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<tr>
<td>2000</td>
<td>STS-101</td>
<td>ISS-2A.1</td>
<td>ISS-2A.2</td>
<td>ISS-6A.1</td>
<td>ISS LON</td>
<td>Reimbursable Flight</td>
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<tr>
<td>2001</td>
<td>STS-102</td>
<td>ISS-6A.1</td>
<td>ISS-6A.2</td>
<td>ISS-6A.1</td>
<td>ISS LON</td>
<td>STS-122</td>
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<tr>
<td>2002</td>
<td>STS-107</td>
<td>ISS LON</td>
<td>ISS LON</td>
<td>ISS LON</td>
<td>ISS LON</td>
<td>STS-122</td>
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<tr>
<td>2003</td>
<td>STS-116</td>
<td>ISS LON</td>
<td>ISS LON</td>
<td>ISS LON</td>
<td>ISS LON</td>
<td>STS-122</td>
</tr>
</tbody>
</table>

Source: 3/18/99 FAWG
» SPACEHAB, Inc. has a proven record in commercial human space.
» We look forward to working with the NRO team towards the spaceflight of payloads on SPACEHAB.
» The Space Station era has begun, and
» SPACEHAB is there...
The nanoSat Payload Ejection System

Steven Huybrechts
Space Vehicle Technologies Branch

Space Vehicles Directorate
Air Force Research Laboratory
Kirtland AFB, New Mexico
Overview
Space Vehicle Technologies Branch

**Vision**

Revolutionize
Space Vehicle Technology
to Meet
Future Warfighter Requirements

**Mission**

Conduct
Innovative Space Vehicle Research, Development, and Transition
of
Advanced Power, Thermal Management, Structures, and Controls Technology
to
Support Global Engagement
Facilities
Space Vehicle Technologies Branch

- Composite Lab
  - Filament Winding
  - Pultrusion
  - Carbon-Carbon
  - CT-Scanning
  - Mechanical Testing
- Acoustics Lab
- Energy Generation Lab
- Energy Storage Lab
- Thermal Research Lab
- Large Deployable Structures Area
- Precision Structures Lab
- Active Controls Lab
- Isolated Controls Facility
The University nanoSat Program

Leverage
Innovating Thinking at U.S. Universities

Demonstrate
Nanosat Technologies &
Advanced Mission Concepts

Technologies of Interest
Formation Flying
Miniaturized Sensors
Micro-Propulsion
Guidance & Navigation
Multifunctionality
Collaborative Processing
# Program Participants

<table>
<thead>
<tr>
<th>Program</th>
<th>Institution</th>
<th>Principal Investigator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three Corner Sat</td>
<td>Arizona State U</td>
<td>Reed</td>
</tr>
<tr>
<td>Three Corner Sat</td>
<td>U of Colorado at Boulder</td>
<td>Hansen</td>
</tr>
<tr>
<td>Three Corner Sat</td>
<td>New Mexico State U</td>
<td>Horan</td>
</tr>
<tr>
<td>Emerald</td>
<td>Stanford U</td>
<td>Twiggs</td>
</tr>
<tr>
<td>Emerald</td>
<td>Santa Clara U</td>
<td>Kitts</td>
</tr>
<tr>
<td>ION-F</td>
<td>Utah State U</td>
<td>Redd</td>
</tr>
<tr>
<td>ION-F</td>
<td>U Washington</td>
<td>Campbell</td>
</tr>
<tr>
<td>ION-F</td>
<td>Virginia Tech U</td>
<td>Hall</td>
</tr>
<tr>
<td>Solar Blade Nanosat</td>
<td>Carnegie Mellon U</td>
<td>Whittaker</td>
</tr>
<tr>
<td>Constellation Pathfinder</td>
<td>Boston U</td>
<td>Spence</td>
</tr>
</tbody>
</table>

![Satellite Diagrams]

3-Corner Sat  | Emerald  | ION-F  | Constellation Pathfinder  | Solar Blade NanoSat
Three Corner Sat Constellation
Arizona State, New Mexico State, University of Colorado

Constellation of Three Identical nanoSats

Stereo Imaging
Formation Flying
Cellular Phone Communications
Innovative Command and Data Handling

Launch

On-Orbit
Validation of Spacecraft Formation Flying Technologies

- GPS Based Relative Position Sensing
- Direct Intersatellite Communications
- Position Control Using Tether, Drag Panels, & Colloid Microthrusters
- Formation Flying Through a Distributed Ionospheric Science Exp

Stacked  Tethered  Separated
Ionospheric Observation
nanoSat Formation

Distributed System Science & Cutting Edge Technologies

Formation Flying & Management
Inter-Satellite Cross-Links
Distributed Ionospheric Data
Small Satellite Subsystems
Internet Control of a Distributed Space System
1kg, 1W Nanosats Capable of Returning
High-quality, 3-pt Vector Magnetic Field Measurements

Pathfinder for a 100-200 nanoSat Mission to Map
the Dynamic Magneto-Sphere
for Robust Prediction
of Space Weather

Autonomous Spin-Stabilization

Measurement of
Low Level DC Magnetic Fields

Launched From "Mother Ship"
Providing a Central Point for
InterSatellite Communication
Demonstrate HelioGyro Solar Sail Technology

Attitude Control

Position Changes

Spiral Out Past the Moon

Collective & Cyclic Pitching of 20m Blades
Creates Propulsion from Photon Pressure
The nanoSat Payload Ejection System

Provide Low-Cost Launch Opportunity for University nanoSats

Goal: Flexible, Reusable Design

Preferred Option: OSP/Pegasus
Higher Cost
All nanoSats Launch Together
Minimal Ejection System
Desirable Orbit

Backup Option: Shuttle ‘SHELS’ System
Lower Cost
Requires 2 Separate Launches
Increased Ejection System Complexity
Solar Blade Dropped
Total Mass (With Support Structure) 225 kg

OSP Payload Envelope
Shuttle Hitchhiker Experiment
Launch System (SHELS)
Shuttle Hitchhiker Experiment
Launch System Layout

35” Approx.

37” Approx

42.5”

42.5”

24”

281 kg

288 kg

ASU

UCB

NMSU

USU

UW

VT

Stanford

Santa Clara

Stanford ORION

3^Sat

USU

BU

EMERALD

Stanford ORION
Conclusions

*Multiple & Varied*
Technology Demonstrations
Scientific Measurements

Significant Payoff for Minimal Funding

*Follow-on Launches Likely*

Industry/Government Partners
*Encouraged to Participate*
Space Test Program (STP)

RideShare Conference
16 Apr 99

Maj Michael Ward
SAF/AQSL
703-588-7376
Space Test Program Outline

- Program Description
- SERB Process
- Recent Missions Flown
Space Test Program Description

- Provide spaceflight and on-orbit operations for highest priority DoD space experiments, based on rankings of annual DoD Space Experiments Review Board (SERB)
  - SECDEF letter (6 Nov 95) reaffirmed this STP mission
  - STP does not fund or provide the space experiments

- STP investment pays dividends in demonstrating new space technologies for military and commercial applications
  - STP demonstrated key technologies and flew prototype for the GPS constellation
  - STP demonstrated operational capabilities of advanced comm technologies (EHF spread spectrum, K band) used in Milstar, DSCS III, TDRSS

- To date, STP has flown 426 experiments on 135 missions since 1967. Of these, 113 missions have been successful (84% success rate.)
Space Test Program
SERB Process

1. Services rank and submit experiments to DoD SERB
2. DoD SERB evaluates and ranks candidates
3. STP gets SERB list and funding from SAF/AQS
4. STP provides spaceflight

NAVY
ARMY
BMDO
NRO
AF
DoD SERB
DoE
SAF/AQS
SMC/TEL
SECRETARY OF THE AIR FORCE
ACQUISITION
Held 13-15 Apr 99 @ ANSER facilities, Arlington, VA

43 candidates addressed the following technology areas:

- Communications
- Threat Warning
- Surveillance
- Microsatellites
- Subsystem Improvements
- Space Weather/Environmental Monitoring

See website at http://www.safaq.hq.af.mil/aqsl/spacetest

- Get a DoD sponsor, usually a lab or systems center
- Fill out 1721 paperwork (request for spaceflight)
- Meet Service-level SERB prior to DoD SERB
- Meet DoD SERB in Nov 00
Space Test Program
Recent Missions Flown

STS-95 29 Oct 98 from KSC
- NPS-901 (Mission S94-D) Petite Amateur Navy Satellite (PANSAT)
- NRL-704 Be-7 Measurement in Low Earth Orbit (WAKEBE/TASBE)
- PL-504 (Mission S96-4) 60 Kelvin Thermal Storage Unit (CRYOTSU)
- ASPWS-701 Cell Culture Module (CCM)

STS-88 4 Dec 98 from KSC
- NRL-402 Shuttle Ionospheric Modification with Pulsed Localized Exhaust (SIMPLEX)
- PL-606 MightySat-1 (Mission P97-1)

ARGOS freeflyer on Delta II (P91-1) 23 Feb 99 from VAFB
- AL-601 Electric Propulsion Space Experiment (ESEX)
- ECOM-501 Extreme Ultraviolet Imaging Photometer (EUVIP)
- GL-806 Critical Ionization Velocity (CIV)
- NRL-206 High Temperature Superconductivity Space Experiment (HTSSE II)
- NRL-304 High Resolution Airglow/Aurora Spectrometer (HIRAAS)
- NRL-505 Coherent Electromagnetic Radio Tomography (CERTO)
- NRL-701 Global Imaging Monitor of the Ionosphere (GIMI)
- NRL-801 Unconventional Stellar Aspect (USA)
- ONR-502 Space Dust Experiment (SPADUS)
EELV Secondary Payload Adapter (ESPA)

Capt Scott A. Haskett
USAF Space Test Program
SMC/TELO
(505) 846-8570

Overview

- ESPA Motivation
  - Small Satellite (SmallSat) Uses
  - US SmallSat Launch Capabilities

- ESPA Program
  - Characteristics and Capabilities
  - Current Activities/Far-Term Plan
  - ESPA Customers

- Conclusion
Small Satellites (<200 kg)

- Space Experiments
  - Inexpensive Way to Demonstrate New Space Technology
  - Perform Space Experiments
  - Test Operational Prototype Hardware
- AFSPC Researching Operational Missions for Smallsats
  - Space-Based Radar, Space Support

US SmallSat Launch Capabilities

- US Medium/Heavy ELVs Have No Built-in Secondary Payload Capabilities
  - Secondary launches are "custom" missions
- Cheapest US Booster: OSP
  - Orbital/Suborbital Program (OSP) uses Minuteman II, Pegasus XL stages
  - Dual-Satellite launch on OSP costs ~$14M
- Least Expensive SmallSat Launch Today Costs $7M
EELV

- EELV Launchers Are Very Capable
  - At least 58% of manifested DoD EELV Medium Missions have >2000lbs margin
- EELV Has No Requirement for Secondary Payloads
- ESPA Uses EELV Margin to Launch up to Six SmallSats in Addition to the Primary Payload

ESPA Characteristics

- Cylindrical Structure, 24” tall
- Est. Empty Mass: 114 kg (250 lbs)
- Holds Six SmallSats + Primary Payload
  - SmallSats: 30-inch cube, up to 220 lbs
  - ESPA projected maximum: 910 kg (2000 lbs) “fully loaded”
- Design Allows Secondary Separation Before Primary Separation (if needed)
ESPAG Impacts to Primary

- **Negative:**
  - Raises Primary Payload 24"
    - Reduces Usable Volume in Fairing
    - Raises CG
  - Effects can be Minimized by Optimizing Primary Payload Adapter

- **Neutral:**
  - Design Replicates EELV Standard Interface Plane to Primary
ESPA Impacts (continued)

- Neutral (continued):
  - Minimum Interaction between Primary and Secondaries
  - Shockless/Non-Pyro Separation Systems for Secondaries

- Positive:
  - Greater Payload Mass Reduces Vibration of Payload Stack
  - *Vibration Isolation (Soft Ride)*

Vibration Isolation

- Reduces Dynamic Response of Secondary Equipment by at Least a Factor of 2
  - Secondaries have separate isolation systems also

- Proven Technology
  - Taurus: GFO (~60% isolation)
  - Taurus: STEX (~85% isolation)
  - OSP Flight 1 (Scheduled September 99)
Isolation on GFO

ESPA Program Details

- Joint STP-AFRL/VSD Program
  - Estimated Non-Recurring Cost: $4.4M
- ESPA Special Study Initiated by EELV SPO April 99
- AFRL Will Build One Qualification Model, One Flight Model
  - PDR June 99, CDR June 00
- IOC FY02; Hoping for Launch in FY 03
  - DMSP, GPS, SBR
ESPA Flight 1

STP Budgeting for First Flight Integration Costs
- Cost-sharing anticipated for any non-STP payloads

Mission Guidelines
- Secondary Manifest Managed by STP
- Secondaries delivered on time or don’t fly
- Primary Drives Umbilical Connections
- Secondaries “Dead” Until Release

Far-Term ESPA Plan

STP Researching Cooperative Agreement with EELV Prime Contractors
- Primes procure ESPA, making it optional on any DoD EELV Medium mission
- ESPA available to commercial market

Secondary Manifest Managed by Primary ESPA Customer (e.g. NASA, STP) or Third Party (e.g. USRA)
Estimated Recurring Costs

- ESPA Cost: $700,000 to $900,000
  - $600,000 for ESPA cylinder & primary isolation system
  - $50,000 per secondary isolation system
- Estimated Integration Costs: $1.0M
- ESPA Goal: Keep Cost per Satellite (fully-loaded ESPA) Less Than $500K
- Potential Customers Excited by Low-Cost Launch Prospects

ESPA Customers

- "Road Show" Briefing Given to Potential ESPA Customers
- AFSPC/NASA/NRO Partnership Council
  - General Myers, Mr. Goldin, Mr. Hall
- SMC
  - EELV SPO/Boeing/Lockheed-Martin
  - Action-Officers at GPS, DMSP, DSCS
  - Presentations Planned for PMs
- HQ AFSPC DR/DOY/XPX
ESPAN Customers (cont.)

- Naval Research Lab
- NASA
  - Goddard SFC
  - Jet Propulsion Laboratory
  - Assistant Administrators, KSC (scheduled)
- Industry/Academia
  - University Space Research Association
  - Ball Aerospace
  - AIAA Conferences (scheduled)

Conclusion

- Small Satellites are Useful, But US Lacks SmallSat Launch Infrastructure
  - Hard to fulfill STP mission
  - Potential impact to future AFSPC missions
- ESPA Carries Up to Six SmallSats and Offers "Soft Ride" to Primary and Secondary Payloads
- Launch Cost Per Satellite Drops from $7M-$10M to $320k to $850k
NASA's Pucksat Payload Adapter

Presented At
EELV Secondary Payload Symposium

Aerospace Corporation
El Segundo, CA

March 31, 1999
Presentation Outline

- Pucksat Concept
- Pucksat Design and Payload Configurations
- Major Structural Interfaces
- User Accommodations
- Milestones
- Cost & Schedule
- Lessons Learned
- Points of Contact
- Conclusions

"Fabrication Drawings Exist for a Structure to Carry Small Payloads to Utilize L/V Excess Performance"
Pucksat Concept
Background

- Historically Delta II launches have had payload margins suitable for small satellites. For example, Landsat-7 has 1152 kg margin.

- Pucksat concept created to provide increased access to space by making efficient use of payload margins.

- Goal is to provide Delta II 2nd stage compatible standard structure capable of enabling variety of science missions with wide range of satellite configurations.

- Example missions and configurations are as follows:
  - Pucksat Dedicated Mission Configuration
    Entire spacecraft dedicated to a single experimenter.
  - Pucksat Instrument Carrier Configuration
    Spacecraft utilized by two or more experimenters.
  - Pucksat Multiple Payloads Carrier Configuration
    Spacecraft utilized to dispense multiple small payloads.
  - Multiple Pucksats Stacked Configuration
    Suitable for constellation mission.
Golden Directive

"Launch 12 Small Payloads per Year With an Increase Within 3 Years to 24 per Year"

Initially:

5 Code S Payloads
5 Code Y Payloads
2 Code U Payloads
Pucksat Design and P/L Configurations
Pucksat – Side View

1. DIMENSIONS SHOWN: INCHES (mm)

I/F Bolt Attachment Same As Delta II 2nd Stage Forward Ring
Example Solar Array Assembly (User Specified & Designed)

Vertival Panel
(Hole in Panel Optional - ø15.0in. Maximum)
Horizontal Bulkhead
(TWO LIMITING POSITIONS SHOWN AS EXAMPLE)

Notes:
1. Pucksat height is scaleable downward from 38.5in.(978mm) to customer established lower limit.
2. Size of shown vertical panels is 30in. X 30in. (762mm x 762mm)
Pucksat – Plan View

1. DIMENSIONS SHOWN: INCHES (mm)

- EXAMPLE HORIZONTAL BULKHEAD 56.00 (1423) OD MAX (USER SPECIFIED & DESIGNED)
- VERTICAL PANEL
- EXAMPLE SOLAR ARRAY ASSEMBLY (USER SPECIFIED & DESIGNED)
- #86 (#2185) 9.5ft PAYLOAD FAIRING ENVELOPE
- #108 (#2743) 10ft PAYLOAD FAIRING ENVELOPE

Dimensions:
- 38.00 (965)
- 68.00 (1727)
- 62.00 (1575)
- 51.00 (1296)
- 30.00 (762)
Pucksat – Basic Structural Elements

- Upper I/F Ring
- Longeron
- Kinematic Mount
- Example Horizontal Bulkhead (User Provided)
- Fittings
- Panel
- Lower I/F Ring
Pucksat Assembly Drawing
Example Pucksat Payload Configurations

Pucksat as Dedicated Mission or Instrument Carrier
Pucksat as Multiple Payload Carrier
Pucksat as Hybrid Configuration
Pucksat as Stacked Constellation Mission
Major Structural Interfaces
Pucksat Upper and Lower Interfaces

- Upper I/F Ring bolt attachment same as Delta II 2\textsuperscript{nd} stage Forward Ring 56.83" dia. circle (64 bolts).
- Simple stub adapter(s) can be provided to allow variety of different primary payload I/F attachments.
- Lower I/F Ring-Deployable mates to Delta 6306 PAF.
- Lower I/F Ring-Fixed bolt pattern also matches Delta II 2\textsuperscript{nd} stage Forward Ring.
- Optional Lower I/F Ring-Fixed design readily derived from existing design to match EELV standard 62.01" dia. bolt circle (121 bolts).
- See next six charts.
Pucksat Upper I/F Ring Drawing
Pucksat Lower 1/F Ring Drawing - Deployable
Pucksat Lower I/F Ring Drawing – Fixed (EELV)
User Accommodations
Pucksat Payload Capacity

- Empty Mass = 125 kg (275 lbm)
- Maximum Primary Payload = 5000 lbm with cg 60" above I/F
- Vertical Panels
  113 kg (250 lbm) maximum payload per panel
  Payload not to exceed 351 kg (775 lbm) for all six panels combined
  Exterior payload maximum size - 20" x 28" x 30" prism per panel
- Horizontal Bulkhead
  227 kg (500 lbm) maximum payload
  Payload maximum size - 56 in. dia. x 30 in. height cylindrical prism
- Grand Total Maximum Payload Capacity = 578 kg (1275 lbm)
Usable Pucksat Envelope (per panel) - 38.5" Pucksat
Pucksat - Effect On Primary Payload Delta Launch Loads

![Graph showing the effect on primary payload Delta launch loads. The graph plots the launch load ratio (BM_{WP}/BM_{WOP}) against the primary P/L frequency (Hz). The graph includes lines for different load scenarios: 1678 lbm (Primary P/L), 6594 lbm (Primary P/L), and 3000 lbm (Primary P/L).]
Pucksat - Example Harness Requirements

Standard Parts (Green):
1. Pyros and harness for 6306 PAF
2. Brackets to primary P/L
3. One fairing bracket
4. One harness to fairing bracket

Additional Parts (Red):
5. Pyros to primary P/L
6. Upper pyro extension harness
7. Delta II pyro harness
8. Upper pyro extension brackets
9. Primary P/L to Delta harness
10. One fairing bracket
11. Three harnesses to fairing brackets

Pucksat Parts (Blue):
12. Upper harness pull-off brackets
13. Lower harness pull-off brackets
14. Pucksat wire harness
Milestones
Major Milestones

- Concept Study Presentation          02/06/97
- Customer Surveys Completed         08/06/97
- PDR                                07/16/98
- CDR                                10/01/98
- Fabrication Drawings Delivered     11/20/98
Cost & Schedule
## Pucksat Cost

### Pucksat Budget ($995)*

<table>
<thead>
<tr>
<th>Category</th>
<th>First Unit</th>
<th>Recurring</th>
<th>Category</th>
<th>First Mission</th>
<th>Recurring Mission</th>
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<tbody>
<tr>
<td>Fabrication &amp; Assembly</td>
<td>$470K</td>
<td>$270K</td>
<td>Boeing Integration</td>
<td>$4,576K</td>
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<td>Qualification Test</td>
<td>$130K</td>
<td>$130K</td>
<td>Launch Site Support</td>
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<tr>
<td>24 in. PAF Procurement</td>
<td>$78K</td>
<td>$78K Each **</td>
<td>Launch Site Integration Facility</td>
<td>$300K (Shared)</td>
<td>$300K (Shared)</td>
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<tr>
<td>17 in. PAF Procurement</td>
<td>$90K</td>
<td>$40K Each</td>
<td>Payload Attach Fittings</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$768K</td>
<td>$518K</td>
<td>(Assume 5 Added PAF's)</td>
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<tr>
<td>GSFC Manpower</td>
<td>$62K</td>
<td>$31K</td>
<td>Pucksat Structure</td>
<td>$830K</td>
<td>$549</td>
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<tr>
<td>Total</td>
<td>$830K</td>
<td>$549K</td>
<td>GSFC Manpower</td>
<td>$134K</td>
<td>$134</td>
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<tr>
<td>Travel</td>
<td>$54K</td>
<td>$54</td>
<td>Travel</td>
<td>$6,040K (7 P/L's)</td>
<td>$5,759K (7 P/L's)</td>
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<tr>
<td>Grand Total (No Travel)</td>
<td>$863K Each P/L</td>
<td>$822K Each P/L</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

* 01/22/99 GSFC Full Cost Format
** 30% Discount For Purchase of 4 or More
Lessons Learned
Lessons Learned

• Possibly no significant change in primary P/L structure loads.
• Avoid transmitting overly concentrated loads to L/V interface.
• Make early accommodation for wiring & ordnance from L/V.
• Make six side panels fully interchangeable.
• Make primary structure height scaleable.
• Design for maximum possible size primary P/L.
• Make maximum use of inside & outside usable volumes.
• Provide both deployable and non-deployable configurations.
Lessons Learned

(cont’d)

- Create IPT to thoroughly understand users needs ASAP.
- Start early to mitigate customer concerns & develop users.
- Give users options that can be readily incorporated.
- Give users large degree of P/L configuration flexibility.
- Build flight mass simulators for all P/L’s to mitigate launch schedule risk.
Points of Contact
Pucksat Points of Contact

- Programmatic
  NASA/Goddard Space Flight Center
  Bruce Milam
  Code 470
  Greenbelt, MD 20771
  Phone: 301-286-0429
  e-mail: bruce.milam@gsfc.nasa.gov

- Technical
  Swales Aerospace
  Joseph Young
  5050 Powder Mill Road
  Beltsville, MD 20705
  Phone: 301-902-4162
  e-mail: pyoung@swales.com
  Swales Aerospace
  Matt Krebs
  5050 Powder Mill Road
  Beltsville, MD 20705
  Phone: 301-902-4539
  e-mail: mkrebs@swales.com
Conclusions
In Conclusion

- Pucksat is a low cost, mass efficient way to avoid performance waste on the Delta II.
- Pucksat fabrication drawings are completed and ready for production.
- Upper I/F stub adapter(s) can be provided to accommodate variety of primary payload attachments.
- Pucksat Lower I/F Ring readily modified to match EELV standard interface.
- Pucksat can be flown for a total recurring cost of approximately $5.7 M and be ready for payload installation 50 weeks ATP and ready for Delta II integration approximately 79 weeks ATP.

"Currently looking for a flight opportunity"
What Is a Military Spaceplane?

• Reusable System
  - Timely and Routine Delivery of Mission Assets To, Through and From Space
  - Multi-Mission Capable With Interchangeable Payloads
  - Rapid Turn Time

Technology

Ops Demonstrator Availability (5-10 yrs)

• Space Control
  - Recce, protection
• Force Enhancement
  - Recce
• Space Support
  - Spacelift <4Klbs

Orbit Capable MSP Availability (10-20 yrs)

• Much Greater Payload
• More Capability
• Extended On-Orbit Maneuvering

Last Modified: 2/27/99 2:27 PM
Military Spaceplane (MSP)
System Architecture

Reusable First Stage

NASA - Lead
- NASA Cooperative Technologies based on Performance needs
- AF Concentrate on Ops Technologies

Military Spaceplane (MSP)

Payloads Second Stage

AF - Lead
Integrated Technology Needed

Space Maneuver Vehicle (SMV)
Reusable Satellite Bus/Upper Stage

Modular Insertion Stage (MIS)
Low Cost Expendable Upper Stage

All S&T Technology Supports TSTO MSP
TSTO Military Spaceplane

Characteristics:
- **Length**: ~60ft
- **Glow**: ~300-600Klbs
- **Dry Weight**: ~40-80Klbs (configuration dependent)
- **Payload**: 12Klbs
- **Max Speed**: Mach 15-18
- **Orbit Access**: Suborbital
Space Maneuver Vehicle
(Fully Reusable Satellite Bus/Upper Stage)

Characteristics

- Length: 20-25ft
- Loaded Weight: 11-12,000lbs
- Dry Weight: 25-3000lbs
- Payload: 1200lbs
- Payload Bay: 4ft x 7ft
- ΔV Ideal: 10,500-12,000fps
# Space Maneuver Vehicle
*(Fully Reusable Satellite Bus/Upper Stage)*

## Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Length</td>
<td>20-25ft</td>
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<tr>
<td>Loaded Weight</td>
<td>10-12,000lbs</td>
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<tr>
<td>Dry Weight</td>
<td>25-3000lbs</td>
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<tr>
<td>Payload</td>
<td>1200lbs</td>
</tr>
<tr>
<td>Payload Bay</td>
<td>4ft x 7ft</td>
</tr>
<tr>
<td>∆V Ideal</td>
<td>10-12000fps</td>
</tr>
</tbody>
</table>

## Missions

- Sensor/Payload Test
- Reconnaissance
- Surveillance/Inspection
- Space Object ID
- Electronic Warfare

## Employment

- Pop-Up
- LEO Co-orbit Capability
- Fly-By of Higher Altitude Satellites
- Constellation Building
- Gap Filler

## Features

- On Demand Launch
- Recallable/Recoverable
- Short Notice Tasking
- Landing Gear for Runway Recovery
- Up to 12 Months on Orbit
Standardized Payload Container Offers Many Configuration Options to Users

- Standard Tanks & boxes
- Payload Mounting Bulkhead
- Faceted Lower Cover
- Cylindrical Lower Cover

Standard Flat Panels

Remote Manipulator Arm

- Shipping container
- Standardized payload container incorporating vehicle interfaces
  - Electrical
  - Mechanical
  - Fluid

- Contamination control during transit and storage
- Reduced integration and checkout time
- Reduced turn time for payload swapout
AF/NASA "X-40B" Program

- NASA Research Announcement 8-22
  - ~$100M for Pathfinder and experiments
  - $20M congressional add for AF related activities
- AF Participated in Source Selection
- Boeing Advanced Technology Vehicle (ATV) Chosen
  - Very similar to AF Space Maneuver Vehicle (SMV)
  - Cooperative program between NASA and Boeing
- AF is Providing $16.1M S&T Funds to Make ATV More Like SMV
  - Solar array and power system for longer on-orbit time
  - Sensors and algorithms for rendezvous / proximity ops
  - Improved attitude / pointing system
  - Improved reentry maneuvering potential

<table>
<thead>
<tr>
<th>ATV</th>
<th>SMV</th>
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<tbody>
<tr>
<td>Dry Weight</td>
<td>4200 lbs</td>
</tr>
<tr>
<td></td>
<td>3300 lbs</td>
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<tr>
<td>Payload</td>
<td>600 lbs</td>
</tr>
<tr>
<td></td>
<td>1200 lbs</td>
</tr>
<tr>
<td>Velocity Change</td>
<td>7,200 ft/sec</td>
</tr>
<tr>
<td></td>
<td>10,500 ft/sec</td>
</tr>
<tr>
<td>On-Orbit Duration</td>
<td>&lt;12 hr</td>
</tr>
<tr>
<td></td>
<td>12-15 mo</td>
</tr>
<tr>
<td>Design</td>
<td>modular</td>
</tr>
<tr>
<td></td>
<td>integrated</td>
</tr>
<tr>
<td>Engine</td>
<td>low performance</td>
</tr>
<tr>
<td></td>
<td>high performance</td>
</tr>
</tbody>
</table>

* Will Improve With AF Investment

98/99 Congressional Add Spend Plan

- $5.0M Future-X ATV
- $2.5M Propulsion for SMV/Upper Stage
- $2.5M B-52 Releases of X-40A SMV

<table>
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<tr>
<th>AF S&amp;T Investment in Future-X /ATV</th>
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</thead>
<tbody>
<tr>
<td>99</td>
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<tr>
<td>$5.0M</td>
</tr>
</tbody>
</table>

Last Modified: 

Brainstorming 21stCentury. 21Jan99_AFMSPP_KV p 7
X-40B NBL Project

• Project Go-Ahead from Mr. Abbey Jun '98
• Funding Secured, project Kick-off Oct '99
• Objectives
  – Understand issues affecting vehicle design for planned shuttle mission
  – X-40B CDR: Jul '99
  – Need to incorporate into vehicle design prior to CDR
• Notional Shuttle Mission Outline
  – Conduct AF and NASA missions with X-40B during shuttle mission
  – Perform payload swap-out of X-40A via EVA
  – Perform re-fuel demonstration in between AF and NASA missions
X-40B NBL Project (cont.)

- NBL Project to Look at Shuttle Integration / Crew Ops Issues Associated With This Type of Mission
- Specific NBL Objectives
  - Conduct payload swap-out of 1000-1200 lb 4’x4’x’7 containerized payloads
  - Conduct refueling demonstration
  - No contingency EVA objectives
- Schedule to be in the Water 10-12 May ’99
  - Day 1: Install mockup in pool
    Scuba runs to check scenarios
  - Day 2: Run 1 MOD EVA/CB suited run to verify scenarios
    Run 2 CB Ops run/eval
  - Day 3: Run 2 CB Ops run/eval
    Run 2 CB Ops run/eval
# USAF Leveraging Ongoing NASA X-Vehicle Programs

<table>
<thead>
<tr>
<th></th>
<th>X-33</th>
<th>X-34</th>
<th>X-38 (X-CRV)</th>
<th>X-37</th>
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<tbody>
<tr>
<td><strong>Mission:</strong></td>
<td>SSTO Technology</td>
<td>Suborbital Air Launch Technology</td>
<td>Space Station Crew Return (ESA Lift Variant)</td>
<td>Next Generation Space Transportation Technology</td>
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<tr>
<td><strong>Funding:</strong></td>
<td>$980M</td>
<td>$80M + $600M</td>
<td>$70M, AF $16M, Boeing $75M</td>
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<tr>
<td><strong>Flight Regime:</strong></td>
<td>~Mach 13</td>
<td>~Mach 8</td>
<td>On-Orbit &amp; Reentry</td>
<td>On-Orbit &amp; Reentry</td>
</tr>
<tr>
<td><strong>1st Flight:</strong></td>
<td>March 2000</td>
<td>1999</td>
<td>2001</td>
<td>2002</td>
</tr>
<tr>
<td><strong>Technologies:</strong></td>
<td>Airframe, LOX/LH₂ Propulsion, etc.</td>
<td>Operations, LOX/RP Propulsion, etc.</td>
<td>Crew interface, Human factors, etc.</td>
<td>Operations, Payload, H₂O₂ / RP Propulsion etc.</td>
</tr>
</tbody>
</table>

| Potential AF Benefits | Technology for Military Spaceplane | Operations for Military Spaceplane | Help Identify Crew Roles & Responsibilities, Recoverable Upper Stage Technology | Potential to Address Space Maneuver Vehicle Technologies & Ops |

Last Modified: [Date]
Low Cost / Low Risk Demonstrator Is Affordable Alternative To Large Orbital System
Boeing & Lockheed-Martin Concepts

Reference

STS Orbiter

Commercial RLV (Unfunded)

Orbital MSP Options (10-20 yrs)

Two Stage To Orbit Ops Demonstrator Options (5-10 yrs)

Propellant:

- LOX/RP
- LOX/LH₂
- LOX/LH₂
- LOX/LH₂

COST
Space Surveillance

- Space Object Identification
  - Multiple sensor capability
  - Co-orbit
  - Optimized fly-by (lighting, angles, position, etc.)
Where Are We?

• Requirements Documentation Proceeding
• Developing Acquisition Strategy
  – Leveraging NASA Technology
  – Phased Approach
  – Building AF Demonstrator Technology Roadmap
• Focus 1st on Demonstrator
  – Low risk TSTO "Pop-Up" Approach
  – Potential for Cooperation with NASA
• Pace, Cost & Direction of MSP Program Depends on
  – Degree of NASA & AF cooperation
  – AF decisions (via FY00 POM) on funding & priorities
  – Validation of AFSPC requirements
Coleman Aerospace conducts research and development and provides products and launch services associated with missile and space vehicle systems.
PAYLOAD ENVELOPES

LK-2
5400
2500

LK-1
3350
1350
LEOLINK TEAM

- Coleman Aerospace Company
- Israeli Aircraft Industries
- Matra Marconi Space
STATUS

- LK-0 is approved by NASA for use under the SELVS II contract

- LK-1 booster has been ground tested, and is scheduled for flight test in 2001

- LK-2 is conceptual
Overview

» OSP
» Objectives
» The Concept
» The Program
» OSP SLV Description
» Hybrid Description
» Complex Sub-orbital Description
» Simple Sub-orbital Description
» Launch Support Concept
Launch Test Program Objectives

- Use Excess ICBM Assets and Proven Launch Vehicles to:
  
  » Provide Cost-Effective, Highly Reliable Launch Services for Orbital and Ballistic Launch Missions
    - Total Cost < $12 Million (Goal)
    - Launch Reliability > 95%

  » Support Wide Range of Payloads and Orbits

  » Provide Quick Turn “One-Stop” Launch Service Support
    - Booster Selection, Payload Integration, Launch, and Data Reduction Services
Concept

Low Risk
Adapt Proven Designs
To Achieve Launch Requirements

Low Cost
Use Pegasus, Taurus & Minuteman Experience
to Minimize Development
Orbital / Sub-Orbital Program

- Program Elements
  - Orbital
    - Large Payload
    - Hybrid
  - Sub Orbital
    - Complex Payload
    - Single RV
The Orbital Program Element

• The OSP SLV for orbiting small satellites
The OSP Small Launch Vehicle
Payload Envelop
Orbital Configuration
Typical Orbital Flight Profile

- Large Payload Mission Scenario

<table>
<thead>
<tr>
<th>EVENT</th>
<th>TIME</th>
<th>ALTITUDE</th>
<th>RANGE</th>
<th>VELOCITY</th>
</tr>
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<tbody>
<tr>
<td>1 Stage 1 Ignition</td>
<td>0.00</td>
<td>0.00 nm</td>
<td>0.00 nm</td>
<td>0 ft/sec</td>
</tr>
<tr>
<td>2 Begin Pitch Down</td>
<td>2.50</td>
<td>0.01 nm</td>
<td>0.00 nm</td>
<td>102 ft/sec</td>
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<tr>
<td>3 Begin Load Relief</td>
<td>20.00</td>
<td>1.53 nm</td>
<td>0.60 nm</td>
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<td>60.82</td>
<td>16.20 nm</td>
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<td>82.90</td>
<td>28.55 nm</td>
<td>29.44 nm</td>
<td>6,155 ft/sec</td>
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<td>6 Payload Fairing Separation</td>
<td>121.10</td>
<td>53.66 nm</td>
<td>70.66 nm</td>
<td>9,448 ft/sec</td>
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<td>57.19 nm</td>
<td>76.96 nm</td>
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<td>197.40</td>
<td>121.72 nm</td>
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<td>9 Stage 3 Separation</td>
<td>662.86</td>
<td>399.42 nm</td>
<td>1,453.00 nm</td>
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<td>10 Stage 4 Ignition</td>
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<td>1,476.12 nm</td>
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<td>11 Stage 4 Burnout</td>
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<td>400.54 nm</td>
<td>1,688.02 nm</td>
<td>24,851 ft/sec</td>
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<td>12 Payload Separation (Mission Dependent)</td>
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</table>
OSP Large Payload Capabilities

- Orbits
  - Minimum Performance Sun Synchronous 400 nm
    - 750 Pounds Mass
- Insertion
  - Pointing Accuracy 4.0 Degrees
  - Altitude +/- 50 nm
  - Inclination +/- 0.2 Degrees
- Maneuvering and Command Capabilities to Deploy Multiple Payloads
Orbital Enhanced
Capability Options (1 of 3)

- Increased Payload Volume (50" Dia, 60" Length)
  - Fairing Outside Diameter 54" - 50" Interface Ring
- Payload Separation System
  - Pegasus System - 38" Separation System Baseline - Others Optional
- Enhanced Insertion Accuracy +/- 10nm +/- 0.1°
  - Use Pegasus Hydrazine Auxiliary Propulsion System to Circularize Orbit
- Conditioned Air
  - Taurus-Proven System with Fly-Away Ducts
- Nitrogen Purge
  - Pegasus Shroud Standard Feature
Orbital Enhanced
Capability Options (2 of 3)

• Payload Access Panel
  » Accommodated by Pegasus Fairing with Drawing/ICD Change

• Navigation Data
  » Orbital-Developed GPS Position Beacon (GPB) Flown on MTD-2

• Enhanced Telemetry (2Mbps)
  » Baseline Encoder Accommodates UP to 10 Mbps - $10^{-6}$ BER at 2100 nm Slant Range

• Enhanced Contamination Control
  » HEPA Filter Added to Payload Air Condition System
Orbital Enhanced Capability Options (3 of 3)

- Softride for Small Satellites (SRSS)

  - Passive isolation system designed by AFRL through SBIR contract
  - Entire system weighs no more than 25 pounds
  - Replaces bolts that attach space vehicle to launch vehicle
  - Can be used above or below separation system
  - Approximate cost - $200K if baseline for OSP
Soft Ride for Satellites

POC: Dr. Dino Sciulli (505) 846-8256, Mr. Eugene Fosness (505) 846-7883

Taurus - $150K, OSP - $200K

Athena II - $160K

Phase III Task Order Contract in Place for Rapid Study, Design, and Manufacture

![Graphs showing shock response and acceleration for Taurus/STEX and Taurus/GFO](image)}
Typical Program Costs

- Typical Costs
  - Vehicle $ 9,500,000 - Includes Msn Success Payment
  - SE/TA $ 750,000 - $600K to $1,000K
  - Range $ 750,000 - $600K to $1,000K
  - Payload Int $ 250,000 - $250K to $500K Based On Options
  - Booster Refurb $ 500,000
  - Shipping $ 250,000 - $50K to $250K
  - Program Mgmt $ 500,000
  - TOTAL $12,500,000
The Hybrid Program Element

- Flight test opportunity for developmental upper stages
Hybrid Launch Mission H-1
NASA's Upper Stage Flight Experiment

- Minuteman / NASA Liquid Upper Stage Hybrid 1
  » Purpose - Flight Test of Advanced Liquid Upper Stages
  » Uses M55 Minuteman Stage 1/2 and LUS

- Conduct Flight Test
Hybrid Launch Mission H-2 & H-3

- Minuteman / NASA Liquid Upper Stage Hybrid 2 & 3
  » Purpose - Demonstrate Capability to Perform Flight Testing of Advanced Liquid Upper Stages
  » Uses M55 Minuteman Stage One and SR19 Stage 2 with LUS
  » The Liquid Upper Stages will be Different Configurations

- Details of Liquid Upper Stages will be Included in MRD

NO MISSION PLANNED YET
- **Minuteman II 3 Stage Booster**
  
  » Deliver Multiple Payloads on ICBM Trajectories

<table>
<thead>
<tr>
<th>Event</th>
<th>Altitude (nm)</th>
<th>Range (nm)</th>
<th>Velocity (ft/sec)</th>
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<tr>
<td>1 Stage 1 Ignition</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>2 Begin Pitch Down</td>
<td>0.02</td>
<td>0</td>
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<td>3 Max-Q</td>
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<td>6 Shroud Separation</td>
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<td>11 Post Boost Maneuvers/Payload Deployment</td>
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<td>12 Target Aimpoint</td>
<td>107.39</td>
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<td>13 Ground Impact</td>
<td>0</td>
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<td>22,577.6</td>
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</table>
Complex Payload Capabilities

- Vandenberg LF 06 Launch to Kawajalein Atoll.
  » Re-entry Angle 20 to 40 Degrees
  » Multiple Payloads Possible
Complex Payload Capabilities

- Payload Envelope
  - Up To 8 Canisterized Payloads 5.7” x 25”
  - GFP to OSP Contractor

- Mass Properties
  - RV 500 Pounds Mass
  - Rigid Targets 40 Pounds Mass
  - Canisterized Targets 60 Pounds Mass
  - Non-Deployed Hardware
  - Total Payload Weight Range
    300 lbm to 1100 lbm

 Initial Measurements

- 6 Inches
- 66 Inches
- 30 Inches
- 28.5 Inches
Complex Payload Throw Weight Performance

![Graph showing payload weights and range requirements.]

- 300 lbm
- 700 lbm
- 730 lbm
- 1100 lbm

Range (nm)

- γ = 40
- γ = 30
- γ = 20

Range Requirement
The Simple Sub-orbital Program Element

- Support sub-orbital missions that do not require an aerodynamic fairing
Sub-Orbital Single RV Payload

- Minuteman II Stage 1&2, Minuteman III Stage 3
  » Deliver Single Payload in Mark 11 Aeroshell

<table>
<thead>
<tr>
<th>Event</th>
<th>Altitude (nm)</th>
<th>Range (nm)</th>
<th>Velocity (ft/sec)</th>
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<tbody>
<tr>
<td>1 Stage 1</td>
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<td>2 Begin Pitch Down</td>
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<td>8 Stage 3 Thrust Termination/ Payload Separation</td>
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<tr>
<td>9 RV Separation</td>
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<td>23,347.4</td>
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<tr>
<td>10 Ground Impact</td>
<td>0</td>
<td>4,761.81</td>
<td>24,094.5</td>
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</table>
Launch Support Concept

Launch Support Van
Launch Equipment Van
Range Control
Launch Stool
Launch Support Concept

- Launches will be performed from Combination Launch Stool and Umbilical Tower
- Portable Launch Support Van (LSV) and Launch Equipment Van (LEV) Will Contain Launch Support Equipment and Range Interface Electronics
Existing OSD Direction

- OSD Memo dated 28 May 1996
  - Granted conversion of 5 MM IIs into SLVs
  - Requested report on booster conversion and JAWSAT launch to “ensure cost-effective use of government assets without inhibiting the growth and development of the U.S. commercial launch industry.”

- OSP contract was put in place
  - Fixed price contract
    - Removed uncertainty about cost effectiveness issue
  - Demonstration launch (FalconSat) then pure launch service
  - 18 month period of performance
  - 5-year contract life
Spaceport Contracted Agencies

- Alaska Aerospace Development Corporation (AADC)
- Spaceport Florida Authority (SFA)
- Spaceport System International (SSI)
- Virginia Commercial Space Flight Authority / Center for Commercial Space Infrastructure (VCSFA/CCSI)
Space Launch Program

- Space Launch Program Has Five Components

  » Launch Vehicle - Initial Launch Capability 3rd Quarter 1999
  » Spaceport - Contract In Place
  » Soft Ride for Small Satellite - Design Completed
  » Booster Refurbishment - Schedule Varies by Project
  » Transporter/Erector
Cost / Funding Procedures

- Customer Prepares MRD in Conjunction with SMC/TE Functional Lead
  » Services Provided as Required from “Menu”

- Typical Events
  » Customer Develops Requirement
  » SMC/TE OSP Conducts Feasibility Studies
  » Defines Funding Requirements and Schedule
  » Funds Transferred to SMC/TEB
  » Mission Manifested
  » Delivery Order Let
  » Develop Master Mission Schedule & Spend Plan
  » Execute Launch Services
Questions?

- Maj Tony Rivera—Ballistic Launch
  (505) 846-5346

- Maj George Stoller—Orbital Launch Support
  (505) 846-5952
Rideshare Conference
April 15-16, 1999
NASA Headquarters
Kennedy Space Center
Organization
and
Small Spacecraft Launch Services
Albert Sierra
Darren Beddel
NASA ELV Program

NASA Headquarters ELV Requirements Products and Services

KSC Organization Overview

Mission Integration Team (MIT) Philosophy/ Roles

Existing Dual Ride and Secondary Payload Options

Previously Flown Secondary Payloads

Potential Missions for Dual or Secondary Payloads

Key Contacts

Secondary Payload Contact List
KSC ELV Program Objectives

- NASA's Lead Center for the Acquisition and Management of Expendable Launch Vehicle Services
  - NASA's ELV Program was previously distributed across multiple NASA Centers by vehicle class and program function.
  - October, 1997 - NASA authorized the establishment of the Lead Center for the Acquisition and Management of the Expendable Launch Vehicle Launch Services at KSC
  - KSC has established an organization to fulfill this responsibility
- Provide safe, reliable, cost-effective ELV Launches
- Maximize Customer Satisfaction
- Perform Advanced Payload Processing Capability Development
ELV Program Organization

NASA Enterprise Customers
- Human Exploration & Development of Space
- Space Science
- Earth Science

Office of Space Flight
- Deputy AA Operations
- OSF Director for ELV Rqmts
- ELV Flight Planning Board
- Lead Center Director
- Governing Program Management Council

ELV Program Manager
- Chief Financial Officer
- Procurement Office

Associate Director Engineering & Processing Services
- Mission Integration Teams
- Mission Integration & Customer Division
- Vehicle Engineering & Analysis Division

NASA Spacecraft Programs

HQ Safety & Mission Assurance
ELV REQUIREMENTS
POLICY

EXPENDABLE LAUNCH VEHICLES

- CSLA AGREEMENT WITH INDUSTRY
- DEVELOP/UPDATE NASA POLICY DIRECTIVES(NPD) ON ELV MANAGEMENT
- DEVELOP/COORDINATE INTERNATIONAL MOA'S RE: SECONDARY PAYLOADS (I)
- REVIEW AND SEEK INDEMNIFICATION AUTHORITY (G)
- COORDINATE/REVISE ELV ACQUISITION GUIDELINES (H)
- SUPPORT REVIEW/COMMENT ON PROPOSED LEGISLATION (G)
- REVIEW AND REVISE ELV MANPOWER LEVELS / SKILLS MIX
- LEVEL OF TECHNICAL INSIGHT AND OVERSIGHT EMPLOYED
- ALTERNATIVE WAYS OF DOING BUSINESS
• ASSISTANT SECRETARY OF AIR FORCE (ACQUISITIONS)
• ASSISTANT SECRETARY OF AIR FORCE (SPACE POLICY & PLANS)
• DOD SS&T DIRECTOR
• DIRECTOR OCST
• BASE COMMANDERS (45TH & 30TH)
• OSTP SCIENCE & TECHNOLOGY
• OMB NASA BUDGET EXAMINERS
• CONGRESSIONAL STAFF (HOUSE / SENATE)
• ELV INDUSTRY (VICE PRESIDENT AND SENIOR MANAGER LEVEL)
• SPACECRAFT INDUSTRY (VICE PRESIDENT AND SENIOR MANAGER LEVEL)
• INTERNATIONAL ELV D.C. REPS (NASDA / ARIANE)
• AIAA DIRECTOR
• IAA SMALL SPACECRAFT TECHNOLOGY COMMITTEE
• SENIOR INTERNATIONAL AGENCY PERSONNEL
ELV REQUIREMENTS
INTERNAL PRODUCTS AND SERVICES

• PROVIDE POLICY FOR OBTAINING OFFICE OF SPACE FLIGHT
  PROVIDED/ARRANGED SPACETRANSPORTATION SERVICES FOR NASA AND NASA-
  RELATED PAYLOADS

• PROVIDE POLICY AND DIRECTION TO THE ELV PROGRAM OFFICE AT KSC
  – LAUNCH SERVICES RISK MITIGATION POLICY FOR NASA-OWNED /SPONSORED PAYLOADS
  – TECHNICAL INSIGHT/OVERSIGHT OF ELV LAUNCH SERVICES TO ASSURE MISSION
    SUCCESS
  – EXPENDABLE LAUNCH VEHICLE (ELV) LAUNCH SERVICES PRELAUNCH REVIEWS

• IDENTIFY, AGGREGATE LAUNCH REQUIREMENTS
  – DEVELOP ACQUISITION STRATEGIES TO MEET REQUIREMENTS
  – IDENTIFY / INITIATE NEW SERVICES
  – ANTICIPATE / RESOLVE LAUNCH CONFLICTS
  – NEGOTIATE / ARRANGE REQUISITE FACILITIES

• CHAIR ELV FLIGHT PLANNING BOARD
  – BASELINE, MISSION LAUNCH PLANNING (VEHICLE / DATE)
  – IDENTIFY / RESOLVE LAUNCH CONFLICTS
DOD - PENTAGON

- MOA'S FOR LAUNCH SERVICES SUPPORT
- ANNUAL ELV REQUIREMENTS LETTER
- REQUEST / NEGOTIATE USE OF DOD FACILITIES / RESOURCES
- IDENTIFY AND RESOLVE LAUNCH CONFLICTS
- NEGOTIATE COSTS FOR USAF SERVICES
- REVIEW DOD CONTRACTS AND RFP'S
- COORDINATE PROCUREMENTS / NEGOTIATE MOA
- SERVE AS NASA REP ON STP PAYLOAD REVIEW BOARD
- SERVE AS NASA REP ON DODO LAUNCH INFRASTRUCTURE BOARD
- IDENTIFY AND COORDINATE CONSISTENT NASA/ DOD POLICY FOR COMMERCIAL ACCESS TO EXCESS FACILITIES / SERVICES
- PARTICIPATE IN GAO REVIEWS OF SERVICES PROVIDED BY NASA
ELV REQUIREMENTS
FOREIGN LAUNCH VEHICLE POLICY

- NATIONAL SPACE TRANSPORTATION POLICY REQUIRES ALL US GOVERNMENT PAYLOADS BE LAUNCHED ON VEHICLES MANUFACTURED IN US
  - UNLESS EXCEPTION BY PRESIDENT
  - OR INTERNATIONAL COOPERATIVES WHERE LAUNCH ON NO-FUNDS EXCHANGED BASIS WITH FOREIGN PARTNER

- OSTP IS RESPONSIBLE FOR FACILITATING INTERAGENCY REVIEW OF ANY EXCEPTIONS

- INTERAGENCY AGREEMENT THAT POLICY NEEDS REVIEW

- NASA IS CONDUCTING AN INTERNAL REVIEW OF THE POLICY

- NASA SEEKS TO REFINE DEFINITION OF PAYLOAD TO EXCLUDE INSTRUMENTS OF TBD $$$
ELV REQUIREMENTS
EXTERNAL PRODUCTS AND SERVICES

CONGRESS
• PREPARE / SUPPORT ADMINISTRATOR MEETINGS WITH MEMBERS
• BRIEF STAFFERS ON ELV PROGRAM / RESPOND TO INQUIRES
• RESPOND TO CONSTITUENT CONCERNS
• COMMENT / REVIEW DRAFT LEGISLATION
• DEVELOP CONGRESSIONAL REPORTS

ELV INDUSTRY
• MANIFEST CONFLICT RESOLUTION
• NEGOTIATE / COORDINATE CSLA AGREEMENTS FOR HQ SIGNATURE
• RESPOND TO CUSTOMER SURVEYS
• STATUS ON EXTERNAL ENVIRONMENTS AFFECTING ELVS
• NEW SERVICES TO MEET NEW DEMANDS

INTERNATIONAL
• FACILITATE UNDERSTANDING OF US ELV CAPABILITY
• FACILITATE UNDERSTANDING OF COOPERATIVE PROCESS WHERE ELV LAUNCH SERVICE IS PROVIDED
ELV REQUIREMENTS
EXTERNAL PRODUCTS AND SERVICES
EXPENDABLE LAUNCH VEHICLES

OMB
• PRESENT NASA INTEGRATED ELV BUDGET
• RESPOND TO INQUIRIES ON ELV COSTS

DOT
• DEVELOP / NEGOTIATE MOA (UELV LICENSE)
• AGENCY FOCAL POINT FOR DOT LIASON ON ELVS
• COORDINATE AGENCY REVIEW OF DOT COMMERCIAL LICENSES / REPORTS / INSURANCE ASSESSMENTS / REGULATIONS
• PARTICIPATE ON COMSTAC WORKING GROUPS

DOE
• SUPPORT INTERAGENCY NUCLEAR SAFETY REVIEW PANEL

OSTP
• SERVE AS NASA ELV REP ON WORKING GROUPS FOR NATIONAL SPACE POLICY
• PROVIDE STATUS ON ELV PROGRAMS AND PROCUREMENTS
ELV REQUIREMENTS
HOW TO GET A NASA LAUNCH SERVICE

- SCIENCE ENTERPRISE AO
  - PROPOSALS TO MEET SCIENTIFIC OBJECTIVES OF THE AGENCY
  - AO PROVIDES GUIDELINES FOR SPACECRAFT AND LAUNCH VEHICLE

- THE PROPOSAL(S) SELECTION ON SCIENTIFIC MERIT

- SCIENCE ENTERPRISE BRINGS THE NEW REQUIREMENT TO THE FLIGHT PLANNING BOARD

- THE NEW REQUIREMENT IS APPROVED BY THE BOARD
  - LAUNCH DATE
  - LAUNCH VEHICLE(S)
  - CO-MANIFEST?
  - LAUNCH SERVICE CONTRACT IN PLACE?

- DIRECTION TO KSC TO PROCUREMENT THE LAUNCH SERVICE

- KSC ACQUIRES AND MANAGES THE LAUNCH SERVICE
# ELV AND UPPER STAGES MANIFEST

<table>
<thead>
<tr>
<th>CY '99</th>
<th>CY '00</th>
<th>CY '01</th>
<th>CY '02</th>
<th>CY '03</th>
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</tr>
<tr>
<td><strong>SMALL CLASS (SC)</strong></td>
<td><strong>PEGASUS (P) - WFF</strong></td>
<td><strong>UELV (UL)</strong></td>
<td><strong>LOW COST BOOSTER (LC)</strong></td>
<td><strong>ATHENA I (AI)</strong></td>
<td><strong>SECONDARY (S)</strong></td>
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<td><strong>DELTA 7920 H (DH)</strong></td>
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<td>[D] ▲ MARS Lander 1</td>
<td>DEEP SPACE 2</td>
<td>1/3</td>
<td>▲ D4</td>
<td>MAP - 11/7</td>
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<td><strong>ATLAS IIAS (IIAS)</strong></td>
<td><strong>DELTA III (DIII)</strong></td>
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<td>GOES - 10/10</td>
<td>[D] ▲ IIA</td>
<td>GOES - 10/10</td>
<td>[D] ▲ IIA</td>
<td>GOES - 10/10</td>
<td>[D] ▲ IIA</td>
<td>GOES - 10/10</td>
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<td><strong>STS / IUS</strong></td>
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* FOR NASA PLANNING PURPOSES

K. PONATOWSKI
Rev 3 3/18/99
ELV REQUIREMENTS
HOW TO GET A NASA LAUNCH SERVICE FOR A SECONDARY SPACECRAFT

• MISSION FROM SCIENTIFIC OR EDUCATIONAL ORG (US OR INTERNATIONAL COOPERATIVE)

• CONTACT THE KSC ELV PROGRAM OFFICE
• FILL OUT SECONDARY PAYLOAD QUESTIONNAIRE (USERS GUIDE)
• KSC TO DETERMINE WHAT NASA MISSIONS HAVE EXCESS MARGIN
  – (OR USAF GPS MISSIONS)
• SPACECRAFT AND ORBIT COMPATIBLE
• FIND AN ENTERPRISE SPONSOR:
  – SPACE FLIGHT
  – AERO-SPACE TECHNOLOGY
  – EARTH SCIENCE
  – SPACE SCIENCE

• APPROVED AT THE FLIGHT PLANNING BOARD
# NASA ELV Long Range Planning


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- **WEST COAST LAUNCHES**
Mission Integration Teams

Features:
- Total management of mission integration process
- One team per mission (30 active)
- Core team membership drawn from ELV Program
- Expanded core team includes all other support functions
- Customer point of contact
- Launch services mission point of contact

Director, ELV Launch Services
Mission Integration Team
Specialized customers

Launch Service Manager
Launch Site Integration Manager
Mission Integration Manager
Integration Engineer

Procurement, Finance
Launch Service contractor
KSC Range, support contractor, safety, launch operations, others
Discipline Engineers, Mission Assurance, others
Extended MIT Members

MIM - Team Lead
GSFC and JPL
Resident Offices
Launch Service Provider
Spacecraft Launch Vehicle Integrator

Integration Engineer:
Mission Analysts
Discipline Engineers
Huntington Beach and Denver Resident Offices

LSIM:
Range Safety
VAFB Resident Office
KSC Communications
KSC, Range, Contractor Support Orgs

LSM:
Business Management
Finance
Procurement
Primary Customer Interface for Mission Specific Integration

- Chair and Manage (KSC) Mission Integration Team (MIT)
- Overall Mission Management (technical, contract deliverables, budget, schedule, etc.)
- Co-Chair Overall Integration Working Group Meetings with Launch Service Provider
- Responsible for Mission Unique Approval & Budget
- Contracting Officer Technical Representative (COTR) for Mission Unique
- Approval of the contractual deliverables after coordination and review by MIT
Coordinates and Leads KSC Engineering Effort

• Responsible for Technical Content of Mission Specific & Other Docs
• Leads Resolution of Technical Issues on the Program
• Establishes Engineering Priorities, coordinated with MIM
• Identifies Issues to Engineering Management that Require Engineering Review Board (ERB)
• Maintains Awareness of Vehicle History for Vehicle assigned to Mission
• Works with Resident Office to organize and accomplish hardware/software reviews
Launch Service Manager (LSM) Responsibilities

Provides Program & Business Management for Launch Services Contracts

- Assesses and works Programmatic impacts and changes across the fleet
- COTR and Primary Interface to Contractor for core vehicle
- Authorizes, reviews and provides business assessment of early mission studies, task orders, change orders, and mission unique
- Financial Management
  - Budget Development and Execution
Launch Site Integration Manager Responsibilities

- Provides planning and coordinates support for all aspects of payload customer stand alone activities at the launch site (e.g., facilities, schedules, safety, budget, networks, communication, etc.)
  - Chairs Ground Operation Working Group Meetings
  - Develops the Launch Site Support Plan
- Assures payload customer requirements and schedules for integrated launch site activities are coordinated with the launch vehicle (e.g., PRD inputs, countdown schedules, procedure inputs)
- Serves as the NASA point-of-contact for launch vehicle activities at the launch site (e.g., integrated procedure review, range support, schedules, reviews, etc.)
- Coordinates Launch Management activities
  - Management Reviews, seating charts, dress rehearsals
  - Supports NASA Launch Manager
• **LSIM Functions**
  - Combines the old LSSM and LOM functions that NASA used to have
  - Provides one interface at the Launch Site to do payload and launch vehicle integration, scheduling and ops planning

• **Boeing - PGOC Support Services Contract**
  - Support to MIT
  - Technology support to Engineering

• **Engineering Interfaces**
  - Integration Engineer functions as technical lead
  - Individual engineering disciplines interface with their counterparts at the Launch Service Provider and Spacecraft Project
Dual Ride Options

- Existing UELV, SELVS-KSC, and Med Lite Contracts have provisions for Dual Rides (Co-manifested)

- Dual Payload Attach Fittings also available to fly secondary payloads

- Ordering period is 18 to 30 months depending on contract

- Mass capability from approximately 150 kg to 1300 kg

- Volume capability from approximately 26” Dia x 22” to 95” Dia x 70”

- Pegasus-XL, Standard Taurus and Delta 732x/742x vehicles available
  - MELVS contract for Delta 792X is “sold out”
  - Larger vehicles TBD under NLS procurement which is currently active
Payload mass typically limited by orbit requirements, not by structural capability

Figure D-6. Dual Payload Attach Fitting (DPAF) Configuration.
Payload mass typically limited by orbit requirements, not by structural capability

Figure D-7. Load Bearing Secondary Configuration
DUAL PAYLOAD ATTACH FITTING (DPAF)

Both payload interfaces would be Boeing 37C payload interfaces.
Secondary Payload Options

- Secondary Payload (SP) Requirements
  - SP shall present no hazard (ordnance, radiation, contamination etc) to the primary payload
  - Acceptance of the SP is subject to approval of the primary payload program manager
  - Primary payload orbit requirements and launch date shall not be affected by SPs
  - Approval of SPs will be considered only if sufficient performance margin exists for the primary mission. Approval could be withdrawn if the margin is unexpectedly reduced

- Existing UELV, SELVS-KSC, and Med Lite Contracts have SP provisions

- Ordering period is 18 to 24 months depending on mission

- Mass capability up to approximately 100 kg

- Volume capability from approximately 11.25” x 19” x 14” to 26” Dia x 22”
Delta Separating Secondary Payload Interface
(Spacecraft Supplied Adapter)

Payload Size Excluding Adapter
11.25" x 19" x 14"
or 10.25" x 19" x 24"

Payload Mass: Including Adapter
45 kg @ 5.0 inch C.G.

Figure 5.5a Example of Payload Adapter Assembly for Separating SPs
Delta Separating Secondary Payload with Adapter,
Launch Vehicle PAF and Clampband

EXPENDABLE LAUNCH VEHICLES
Delta Separating Secondary Payload Attached to Second Stage with GSE
Delta Non Separating Secondary Interface
EXPENDABLE LAUNCH VEHICLES

Payload Size: 13" x 19" x 14"
Payload Mass: 35 kg
Delta Non Separating Interface

Payload Size: 11" x 25" x 24"
Payload Mass: 70 kg

Note: Envelope width is 24.00 inches.
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Example of Dual Mission and 2 Secondary Payloads

EXPENDABLE LAUNCH VEHICLES

Launch Date 12/99

- Vehicle configuration: 7320-10C
- Launch site: SLC-2 at VAFB
- Target launch date: 15 Dec 1999
- Unique mission requirements
  - Dual Payload Attach Fitting (DPAF)
  - GN2 purge requirement (EO-1)
  - T-0 air conditioning (SAC-C)
  - First flight instrumentation
  - Standard DPAF instrumentation
  - Additional shock test support (EO-1 and SAC-C)
  - Thermal analysis for SAC-C
  - 100 lb separation springs (EO-1)
- Secondary payloads
  - Citizen Explorer
  - Munin

First Stage
- Thrust Augmentation Solids
- Oxidizer tank
- Centerbody Section
- Fuel tank
- Wiring Tunnel
- Interstage

Second Stage
- Citizen Explorer
- Second-Stage Miniskirt and Support Truss
- Heliium Spheres
- Nitrogen Sphere

EO-1
- Dual Payload Attach Fitting

SAC-C
- Guidance Electronics
- Munin

Two-Piece Composite Payload Fairing
Unique opportunity existed with USAF Argos Spacecraft which required spacers below PAF
Key ELV Contacts

Mission Integration and Customer Division Chief
Bill Fletcher (407) 853-5761

Mission Integration Branch Chief
Darren Bedell (407) 853-2166

Advance Mission Integration Managers
Frank Stone (407) 476-3625
Tom Shaw (407) 476-3640

Resident Liaison Offices
Laura Weber GSFC (301) 286-6922
Rita Willcoxon JPL (818) 354-4788
Johnathan Stabb JPL (818) 354-2489
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<td>Separating SP 45 kg or Non Separating 70 kg Total margin 105 kg</td>
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Orbital Launch Systems

NRO Rideshare Conference

April 16, 1999
Orbital’s Family of Launch Vehicles
## Pegasus and Taurus Flight Heritage (Cont'd)

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### Pegasus and Taurus Flight Heritage

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<td>DFRF/WR</td>
<td>F5 USAF</td>
<td>STEP-M2</td>
<td></td>
<td></td>
<td>5/19</td>
<td>Std/HAPS</td>
<td></td>
</tr>
<tr>
<td>VAFB/WR</td>
<td>F6 USAF</td>
<td>STEP-M1</td>
<td></td>
<td></td>
<td>6/27</td>
<td>XL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FX-A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DFRF/WR</td>
<td>F7 USAF</td>
<td>APEX</td>
<td></td>
<td></td>
<td>8/3</td>
<td>Std</td>
<td></td>
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<tr>
<td>VAFB/WR</td>
<td>F8 ORBCOM</td>
<td>FM1 &amp; FM2</td>
<td></td>
<td>4/3</td>
<td></td>
<td>Std</td>
<td></td>
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<tr>
<td></td>
<td>ORBIMAGE</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>VAFB/WR</td>
<td>F9 USAF</td>
<td>STEP-M3</td>
<td></td>
<td></td>
<td>6/22</td>
<td>XL</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

DFRF – Dryden Flight Research Facility  
WR – Western Range  
ER – Eastern Range  
VAFB – Vandenberg AFB
Pegasus Air Launch Vehicle

- Pegasus XL is a Winged, 3-Stage Solid Rocket Booster
- Air Launched from L-1011 Carrier Aircraft
- System Mobility Optimizes Cost and Performance
- Commercially-Developed, Government-Certified
- Base of Operations at Vandenberg AFB, CA
L-1011 Carrier Aircraft

L-1011 Carrier Aircraft Payload Services and Launch Operation from Vandenberg.

<table>
<thead>
<tr>
<th>Orbital Carrier Aircraft Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Taxi Weight</td>
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<tr>
<td>Max Gross Take-Off Weight</td>
</tr>
<tr>
<td>Max Landing Weight</td>
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<tr>
<td>Max Zero Fuel Weight</td>
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<tr>
<td>Operating Empty Weight</td>
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<table>
<thead>
<tr>
<th>Captive Carry Mission Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission Radius</td>
</tr>
<tr>
<td>Ferry Range</td>
</tr>
<tr>
<td>External Store Capacity</td>
</tr>
<tr>
<td>Operating Altitude</td>
</tr>
<tr>
<td>Payload Deployment Speed</td>
</tr>
</tbody>
</table>

L-1011 Carrier Aircraft Performance.
Pegasus Capable Launch Sites to Date

Western Range
70° to 130° Inclination

Wallops Flight Facility
30° to 65° Inclination

Eastern Range
28° to 50° Inclination

Kwajalein Atoll
0° to 10° Inclination

Canary Island
Launch Point
Mobile Range
25° Inclination
(Retrograde)

Equator

Orbital
Taurus Launch Vehicle

- Designed for Easy Transportability, Rapid Set-Up, and Launch from an Austere Site
- Capable of Quick Reaction Launch on Demand Scenarios Anywhere in the World

990408.01
Taurus Rapid Response Capability

- Launch on Demand Scenarios  Easily Accommodated with Minimum Site Infrastructure

- Response Time Capability of
  - 8 Days
  - 5 Days
  - 2 Days

Road Transportable

Launch Support Van

Launch Stand Preparations

Launch Equipment Van

Payload and Upper Stack Mate

990409.02
## Orbital's Shared Launch Experience
(56 Payloads on 15 Launches)

<table>
<thead>
<tr>
<th>Launch</th>
<th>Date</th>
<th>Number of Payloads</th>
<th>Payloads</th>
<th>Payload Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pegasus F-1</td>
<td>April 1990</td>
<td>2</td>
<td>• Pegasus • NGRWsat</td>
<td>• Nondeployable Instrumentation Package • Deployable Experiment for Atmospheric Research</td>
</tr>
<tr>
<td>Pegasus F-2</td>
<td>July 1991</td>
<td>7</td>
<td>• 7 Microsats</td>
<td>• Multiple Deployable Satellites for Technology Demonstration</td>
</tr>
<tr>
<td>Pegasus F-3</td>
<td>February 1993</td>
<td>2</td>
<td>• SCD-1 • QXP-1</td>
<td>• Deployable Brazilian Communications Satellite • Deployable Satellite for Communications Demonstration</td>
</tr>
<tr>
<td>Pegasus F-4</td>
<td>April 1993</td>
<td>2</td>
<td>• ALEXIS • QXP-2</td>
<td>• Deployable U.S. Air Force Technology Demonstration Satellite • Nondeployable Commercial Communications Payload</td>
</tr>
<tr>
<td>Taurus T-1</td>
<td>March 1994</td>
<td>2</td>
<td>• DARPA SAT • STEP-M0</td>
<td>• Deployable Classified Spacecraft • Deployable Satellite for Technology Demonstration • Load Bearing to Optimize Mass and Volume</td>
</tr>
<tr>
<td>Pegasus F-6</td>
<td>June 1994</td>
<td>2</td>
<td>• STEP-M1 • FX-A</td>
<td>• Deployable U.S. Air Force Technology Demonstration Satellite • Nondeployable NASA Hypersonic Research Experiment</td>
</tr>
<tr>
<td>Pegasus F-8</td>
<td>April 1995</td>
<td>3</td>
<td>• FM-1 • FM-2 • OrbView-1</td>
<td>• Deployable Communications Satellite • Deployable Communications Satellite • Deployable Remote Sensing Satellite • All Load Bearing to Optimize Mass and Volume</td>
</tr>
<tr>
<td>Pegasus F-14</td>
<td>November 1996</td>
<td>2</td>
<td>• SAC-B • HETE</td>
<td>• Dual Deployable NASA Scientific Satellites • Non Load Bearing Using the DPAF</td>
</tr>
<tr>
<td>Pegasus F-15</td>
<td>April 1997</td>
<td>2</td>
<td>• MINISAT 01 • Celestis</td>
<td>• Deployable Spanish Scientific Satellite • Nondeployable Tertiary Commercial Payload</td>
</tr>
<tr>
<td>Pegasus F-19</td>
<td>December 1997</td>
<td>8</td>
<td>• ORBCOMM-1 (FM 5-12)</td>
<td>• Initial Constellation Launch to Deploy 8 Microstar Satellites • Load Bearing to Optimize Mass and Volume</td>
</tr>
<tr>
<td>Taurus T-2</td>
<td>February 1996</td>
<td>4</td>
<td>• GFO • FM-3 • FM-4 • Celestis</td>
<td>• Deployable Ocean Altimetry Spacecraft for the U.S. Navy • Deployable Microstar Spacecraft for ORBCOMM • Deployable Microstar Spacecraft for ORBCOMM • Nondeployable Commercial Tertiary Payload</td>
</tr>
<tr>
<td>Pegasus F-20</td>
<td>February 1998</td>
<td>2</td>
<td>• SNOF • BATSAT (T-1)</td>
<td>• NASA Deployable Student Payload Under STEDI Program • Commercial Deployable Microstar Satellite • Secondary Load Bearing to Optimize Mass and Volume</td>
</tr>
<tr>
<td>Pegasus F-22</td>
<td>August 1998</td>
<td>8</td>
<td>• ORBCOMM-2 (FM 13-20)</td>
<td>• Second Constellation Launch to Deploy 8 Microstar Spacecraft • All Load Bearing to Optimize Mass and Volume</td>
</tr>
<tr>
<td>Pegasus F-23</td>
<td>September 1998</td>
<td>8</td>
<td>• ORBCOMM-3 (FM 21-28)</td>
<td>• Third Constellation Launch to Deploy 8 Microstar Spacecraft • All Load Bearing to Optimize Mass and Volume</td>
</tr>
<tr>
<td>Pegasus F-24</td>
<td>October 1998</td>
<td>2</td>
<td>• SCG-2 • Winn (I)</td>
<td>• Deployable Commercial Communications Satellite for Brazil • Nondeployable NASA Hypersonic Research Experiment</td>
</tr>
</tbody>
</table>

## Planned Missions

<table>
<thead>
<tr>
<th>Launch</th>
<th>Date</th>
<th>Number of Payloads</th>
<th>Payloads</th>
<th>Payload Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pegasus</td>
<td>1999</td>
<td>2</td>
<td>• ITT • HiTS • SSS • MURLCOM</td>
<td>• NASA Deployable Student Payload Under STEDI Program • Commercial Deployable Microstar Satellite • Secondary Load Bearing to Optimize Mass and Volume</td>
</tr>
<tr>
<td>Taurus</td>
<td>1999</td>
<td>2</td>
<td>• KOMPASAT • ACRIM</td>
<td>• Commercial Deployable Primary Remote Sensing • NASA Deployable Secondary Payload Using the APC</td>
</tr>
<tr>
<td>Pegasus</td>
<td>1999</td>
<td>8</td>
<td>• ORBCOMM-4 (FM 29-36)</td>
<td>• Fourth Constellation Launch to Deploy 8 Microstar Spacecraft • Equatorial Launch</td>
</tr>
<tr>
<td>Taurus</td>
<td>2000</td>
<td>Multiple</td>
<td>• OrbView-4 • Open</td>
<td>• Commercial Remote Sensing Satellite • Available for Booking</td>
</tr>
</tbody>
</table>
Shared Payload Launch Opportunities

To date, Orbital has successfully placed 52 payloads into orbit on 13 Pegasus and Taurus shared launches. Presently, Orbital has launch opportunities available on our launch systems. These launches have capacity available for co-passenger payloads matching the orbit, schedule, mass, and volume parameters, shown in the Table A below. Payloads that can accept these mission parameters should contact Orbital to verify technical compatibility and obtain a launch agreement. In addition, Orbital maintains a listing of known missions that are searching for complementary payloads to share a launch. These missions are listed in Table B.

If any of these payload parameters match your specific needs, you are invited to contact Orbital’s Launch Systems Group business development to further assess mission compatibility and a possible launch assignment on Pegasus or Taurus.

- Check our Orbital launch opportunities on our web site (www.Orbital.com)
- Look for compatible ride share partners
- Register your mission to be considered

### Table A: Mission Orbit Launch Mass Available Volume Available

<table>
<thead>
<tr>
<th>Mission</th>
<th>Orbit</th>
<th>Launch Date</th>
<th>Mass Available</th>
<th>Volume Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pegasus LV-P010</td>
<td>0-5° 550-700 km</td>
<td>Early 2000</td>
<td>20-76 kg</td>
<td></td>
</tr>
<tr>
<td>Taurus LV-T011</td>
<td>Sun-Synchronous 470 km 10:50 a.m.</td>
<td>Mid 2000</td>
<td>90 kg</td>
<td>110 cm Dia x 153 cm Height</td>
</tr>
<tr>
<td>Pegasus LV-P012</td>
<td>0-10° 550-650 km Circular</td>
<td>2001</td>
<td>100 kg Estimate</td>
<td></td>
</tr>
<tr>
<td>OSP LV-013</td>
<td>Sun-Synchronous 12:00 p.m. ±2 hrs or 50-95°, 500-600 km</td>
<td>Early 2000</td>
<td>150 kg +</td>
<td>66 cm dia x TRD Length</td>
</tr>
<tr>
<td>Pegasus LV-P014</td>
<td>45° Inclination 825 km</td>
<td>Mid 2000</td>
<td>140 kg</td>
<td></td>
</tr>
<tr>
<td>Pegasus LV-015</td>
<td>45° Inclination 825 km</td>
<td>Late 2000</td>
<td>140 kg</td>
<td></td>
</tr>
</tbody>
</table>

### Table B: Mission Inclination Altitude Nodal Crossing Launch Date Launch Mass & Volume Available

<table>
<thead>
<tr>
<th>Mission</th>
<th>Inclination Altitude Nodal Crossing</th>
<th>Launch Date</th>
<th>Launch Mass &amp; Volume Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-107</td>
<td>Sun-Synchronous 550-650 km 6 a.m. ±2 hrs</td>
<td>Mid 2000</td>
<td>100 Kg 111.7 cm dia. x 55.6 cm Height</td>
</tr>
<tr>
<td>P-108</td>
<td>Sun-Synchronous 613 km Circular</td>
<td>2002</td>
<td>110 - 275 Kg 109.2 cm dia. x 177.8 cm Height</td>
</tr>
</tbody>
</table>
Pegasus® Equatorial Launch from Kwajalein Atoll
Pegasus® TERRIERS/MUBLCOM Mission Profile

Dual Launch Configuration

L-1011 Drop Launch
h = 39,000 ft

First Stage Ignition
t = 5 sec
h = 141,096 ft

Second Stage Ignition
t = 97 sec
h = 244,170 ft

First Stage Burnout
h = 449,070 ft

Second Stage Burnout
t = 162 sec

Third Stage Burnout
h = 449,070 ft

Second/Third Stage Coast

Third Stage Ignition

Stage 3/HAPS Separation

Payload Fairing Separation
t = 129 sec
h = 340,975 ft

Vandenberg AFB Range Telemetry Coverage

HAPS Burn #1
t = 557-571 sec

Orbit Injection
550 km Circular Sun-Synchronous
Pegasus®/TERRIERS/MUBLCOM
Mission Profile (Cont'd)

Orbit 3
775 x 775 km
Deploy MUBLCOM
t = 3764 sec
Reorient CCAM
t = 3884-3885 sec
HAPS Burn 4
Deorbit
t = 3944-3965 sec

Orbit 2
775 x 550 km
Reorient HAPS Burn 2
t = 751-770 sec

Orbit 1
550 x 550 km
Deploy TERRIERS
t = 631 sec
Reorient Jettison Adapter
t = 691 sec

Orbit 4
460 x 775 km
Reorient HAPS Burn 5
Depletion Burn
5605-5656 sec
Expendable Launch Systems
Delta Launch Vehicle Family Meets New and Emerging Customer Requirements
Delta Family Spans Entire Payload Range

Performance to GTO (185 km x 35,786 km x 27°)
Delta II Program Summary

- The western world’s most reliable launch vehicle
  - 96.9% success since Oct 1977 (127 out of 131 launches)
- One standard of quality for government and commercial customers
  - 12 launches in 1998 (2 government, 10 commercial)
  - 15 launches planned for 1999 (8 government, 7 commercial)
- Secondary payloads successfully flown on 21 missions for Air Force, NASA, and SDIO
  - First flight on Pioneer-C December 1967
  - Last flight on P91-1 Argos February 1999
NASA Med-Lite Program

- Medium Light Expendable Launch Service initiated in February 1996

- Status to date

- Flown (4): Deep Space 1, Mars Orbiter '98, Stardust, Mars Lander '01

- On contract (6): FUSE, IMAGE, EO-1/SAC-C, MAP, Genesis, and Mars Lander '01

- Secondary payload SEDSAT flown on Deep Space 1 October 1998
Delta III Program

- Delta III program approach
  - Commercially developed by Boeing
- Delta II evolution
  - Address launch vehicle market needs for spacecraft up to 3.8 metric tons
  - Based on existing Delta II
  - New cryogenic upper stage and fairing
  - Launch base modifications
- Major Delta III team members
  - Alliant Techsystems
  - Boeing Rocketdyne
  - Pratt & Whitney
  - Mitsubishi Heavy Industries
Evolved Expendable Launch System/Delta IV

- Next evolution of the highly reliable Delta vehicle
- Satisfies government and commercial requirements
- Modular family of launch vehicles from Medium to Heavy capability
- Dual coast capability
  - CCAS ILC 2nd qtr CY2001
  - VAFB ILC 4th qtr CY2002
- Initiating secondary payload study for U.S. Air Force
Delta IV Uses Boeing-Manufactured
Stretched Delta III and Titan IV Fairings

- Delta III's 4-m-dia composite fairing
- Used on Delta IV Medium,
  Delta IV Medium-Plus

- Delta II's 10-ft-dia composite fairing
- Successfully flown 13 times
  • 11 for Motorola Iridium®
  • 2 for Globalstar

- Boeing manufactured 200-in-dia aluminum Titan IV fairing
- 100% success rate over the
  24 Titan IV missions flown

As of 01 October 1996
Secondary Payload Accommodations

Delta IV–M/M+

- Delta III 4-m composite fairing
- New payload adapter
- Delta III cryogenic upper stage

Payload attach fitting

P91-1 Secondary

Delta II-7920 Guidance Section
Secondary Payload Considerations

- Presents no hazard to primary payload
- Requires approval of primary payload program manager
- Satisfies primary payload mission orbit requirements
- Delta has excess performance margin
  - Secondary mission withdrawn if margin reduced
- Compatible with launch times
- Maintains primary payload clearance envelope
- Keeps launch services separate from primary mission
- Complies with range safety requirements
Secondary Payload Integration
Parallels Primary Mission Process

L-36 to 24 mo
L-24 mo

Primary mission
Mission planning

Mission analysis
- Dynamics
- Fairing clearance
- Strength report
- Environments
- Mission MODS

Assembly and checkout

Readiness reviews
Payload fitcheck L-13 mo L-4 mo

Secondary mission
Payload processing

Encapsulation
Astrotech

Integrated procedures
Processing

Integrated Delta team throughout process

Delta II
Vandenberg Air Force Base Facilities
Flight Sequence of Events
Delta IV Medium

T + 249 sec
MEO

T + 279 sec
PLF jettison

T + 4042 sec
Second stage ignition (IGN2)

T + 274 sec
First-second stage separation

T + 861 sec
Second stage ignition (IGN1)

T + 4274 sec
SECO-1

T + 4874 sec
SECO-2

S/C separation

T + 5500 sec
CCAM

Range safety radar (C-band)

Telemetry (S-band)

Ground station

Ground station

Ground station

T0 liftoff

Secondary Payload Mission Sequence
- Initiate after primary mission separation
- Deploy secondary from upper stage
- Remain on upper stage
- End of mission
Delta Program has a Long History Of Secondary Payload Mission Successes

- Secondary payload must be compatible with primary mission
- Generally two year mission integration cycle
- Boeing conducting study on EELV secondary payload adapter
- Next secondary mission for NASA is May 1999
  - Citizen Explorer (University of Colorado)
  - Munin (Sweden)
Delta Payload Planning Information

Mission planning information available from multiple sources

Delta Web Page
http://www.boeing.com/defense-space/space/delta/delta2/guide/
http://www.boeing.com/defense-space/space/delta/delta3/guide/
http://www.boeing.com/defense-space/space/delta/delta4/guide/

Contact Delta Launch Services (714) 896-4321
Backup
## Delta Secondary Payload Missions History

<table>
<thead>
<tr>
<th>Delta No.</th>
<th>Mission</th>
<th>Secondary</th>
<th>Launch Date</th>
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<tbody>
<tr>
<td>55</td>
<td>Pioneer-C</td>
<td>TTS; Cal-NCE</td>
<td>12-13-67</td>
</tr>
<tr>
<td>56</td>
<td>GEOS-B</td>
<td>Cal-NCE</td>
<td>01-11-68</td>
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<tr>
<td>60</td>
<td>Pioneer-D</td>
<td>TTS</td>
<td>11-08-68</td>
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<td>72</td>
<td>OSO-G</td>
<td>PAC</td>
<td>08-09-69</td>
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<tr>
<td>76</td>
<td>TIROS-M</td>
<td>OSCAR</td>
<td>01-23-70</td>
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<tr>
<td>86</td>
<td>OSO-H</td>
<td>TUR</td>
<td>09-29-71</td>
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<tr>
<td>91</td>
<td>ITOS-D</td>
<td>OSCAR</td>
<td>10-15-72</td>
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<td>104</td>
<td>ITOS-G</td>
<td>OSCAR, INTASAT</td>
<td>11-15-74</td>
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<td>139</td>
<td>Landsat-C</td>
<td>OSCAR, PIX</td>
<td>03-05-78</td>
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<tr>
<td>145</td>
<td>Nimbus G</td>
<td>Cameo</td>
<td>10-24-78</td>
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<td>157</td>
<td>SME</td>
<td>UOSAT-A</td>
<td>10-06-81</td>
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<td>166</td>
<td>IRAS</td>
<td>PIX II</td>
<td>01-25-83</td>
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<td>Landsat-D</td>
<td>UOSAT-B</td>
<td>03-01-84</td>
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<td>206</td>
<td>Navstar 11-11</td>
<td>LOSAT-X</td>
<td>07-03-91</td>
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<td>212</td>
<td>Geotail</td>
<td>DUVE</td>
<td>07-24-92</td>
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<td>219</td>
<td>GPS-1</td>
<td>SEDS-1</td>
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<td>221</td>
<td>GPS-3</td>
<td>PMG</td>
<td>06-26-93</td>
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<td>226</td>
<td>GPS-6</td>
<td>SEDS-2</td>
<td>03-09-94</td>
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<td>229</td>
<td>RADARSAT</td>
<td>SURFSAT</td>
<td>11-04-95</td>
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<td>261</td>
<td>Deep Space 1</td>
<td>SEDSAT</td>
<td>10-24-98</td>
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<tr>
<td>267</td>
<td>P91-1 ARGOS</td>
<td>Oersted Sunsat</td>
<td>02-23-99</td>
</tr>
</tbody>
</table>
Atlas Evolution

GTO Capability (klbs)

Atlas II/III Family

- 3.3m/4.2m Payload Fairing (PLF)
- Dual Engine Centaur (DEC)
- 3.1m Interstage Assembly (ISA)
- 3.1m Booster Core (1, MA-5A Sustainer Engine)

Atlas IIAS

Atlas IIIA

Atlas IIIIB

Atlas V (400 Series)

Risk Reduction Initiatives
- 3.8m Common Core Booster (CCB)
- 5 m Cluster PLF
- 3.8 m ISA
- SRBs
- CCB Strap-on

Atlas V (500 Series) (0-5 SRBs)

Atlas V (MLV)

Continually improving value for our customers.

Atlas V Overview Aug99
Atlas V (552) Launch System

Common Core Booster™ Stage
Intersstage Adapter
RL 10 Engine(s)
Centaur Upper Stage
Contraves Fairing
Solid Rocket Boosters
RD-180 Propulsion System

SRM manufacturer—Aerojet
- Identical—interchangeable Solids
- Simple and reliable
  - All ground lit
  - No TVC system—Fixed 3-deg nozzles
  - Monolithic—No segments
  - Ship and shoot

Maximum Mission Flexibility
One - Five SRMs Provide- GTO: 9-19k Lbm, LEO: 24-40k Lbm
Hardware Development Progress

Atlas III Stage Test at NASA/MSFC
Contraves 5-m PLF
Single Engine Centaur Final Assembly Building
Atlas V 11 ft. PLF

RD-180 Engine Final Assembly Building
Atlas V Tank Dome
Atlas V Tank in VTF
Atlas V Tank in AWC
Atlas V Tank in ARL
Honeywell Fault-Tolerant INU
BF Goodrich Data Acquisition System
Atlas V Tank in VTF

Atlas V is accomplishing key development milestones
Atlas V Tailored Critical Design Review Summary

- Series of 12 reviews—4 vehicles and 2 pads
- 34 review days—May 18-July 29
- 8,107 briefing charts in addition to supporting materials
- TCDR Preceded by Several Months of Detailed Subsystem Briefings

TCDR judged as “Excellent” by the Customer and Independent Review Panels
RD-180 Engine Team

Lockheed Martin
Launch Vehicles

American/Russian Rocket
Company Joint Venture
West Palm Beach, Florida

Support US Government Launches
Pratt & Whitney
West Palm Beach, Florida
US Co-Produced Engines

Support International Commercial Launches
NPO Energomash
Khimky, Russia
Russian Produced Engines
RD-180 Update

- RD-180 is a derivative RD-170 engine
  - 70% Parts Commonality
  - Staged combustion LOx-kerosene engine
  - Only Throttatable Production Expendable Engine (47-100%)
- Thrust (100%)
  - 933.4 klb (vac)
  - 860.3 klb (sl)

>16,000 seconds of hot fire testing completed on 20 engines
  - Khimky Russia at NPO Energomash
  - NASA Marshall Space Flight Center

The RD-180 Engine Is Certified For Flight
Common Operational Concept

- Features
  - Common Concept at LC-41 and SLC-3W
  - Common Procedures and Equipment at CCAS and VAFB
    - Minimum Time on Pad
    - Common Processing for All Vehicle Configurations
  - Full Weather Protection in VIF

SLC-3W at VAFB

LC-41 at CCAS
### Atlas V Development Schedule

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**Atlas IIIA**
- BOS
- ILC
- Pathfinder and Launch Processing

**Atlas IIIB**
- CDR
- BOS
- ILC

**Atlas V**
- System TCDR
- AV500 PCR
- HLV PCR
- CCB Struct Qual Test Complete
- Co-Prod Capability
- 5m PLF Sep, Static, Acoustic Test
- VIF C/O Complete
- Pad Complete
- ER GSTPs
- 400/500 ILC
- WR ILC

**Critical Path**
Summary

- Low Risk, Heritage Design
- Standard Payload Interfaces
- High Performance Within Each Vehicle Class
- 4 and 5 meter Payload Fairings
- Modular, Common Element Design
- High Launch Rate
- Efficient Operations
- Commitment to Mission Success

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