Exploration Carriers –
UPC-Orion Launch Opportunities for Lunar Missions

presented to
The Joint Annual Meeting of
LEAG-ICEUM-SRR

Bruce Milam and Ruthan Lewis, Ph.D.
NASA Goddard Space Flight Center
October 30, 2008
Introduction – The Pathway to Space for Science

• “As the National Aeronautics and Space Administration (NASA) resumes human exploration of the Moon within the next decade, the need to accommodate transportation and operation of science, engineering, and technological payloads and investigations in support of NASA’s Vision for Exploration will be prevalent.”

• These accommodations may be associated with “carriers”
  – the means by which payloads are
    • transported by
    • contained in
    • operated on
    • and/or released from the host vehicle, such as Constellation Orion spacecraft
  – Includes
    • management and coordination of payload flight manifest status
    • interaction with the science and user community
    • integration and test of the payloads with the carriers
    • integration and flight operations of the payloads on the launch vehicle and associated spacecraft
Vision for “Exploration Carriers”

*Exploration Carriers will be...* an Orion- or Altair-attached carrier offering standardized H/W, command, and telemetry interfaces and providing rapid access to space for unpressurized cargo to ISS, the moon, and beyond...

- **OPS Concept:** a “one stop shop” where users come to obtain access to space via the Constellation architecture using a plug-n-play interface and established programmatic interfaces
  - Leverages the efficiencies validated during the Attached Payloads era

- Reduces Technical and Programmatic risk
  - Exploration Carriers manage the Orion-Carrier Interface...not the users
  - Safety, Integration, Mission Operations interfaces established and validated
Goddard Space Flight Center (GSFC) Leads NASA’s Exploration Carrier Development, Implementation, and Management

Goddard Space Flight Center is currently…

- characterizing and designing the accommodations aboard the Orion Service Module for Low Earth and Lunar orbits
- Performing initial conceptual design for accommodations aboard the Ares V
- formulating the design of Lunar Surface Systems carriers
We Have Successful Flight Precedence: Apollo
The Apollo Scientific Instrument Module (SIM) Bay flew on three lunar missions enabling detailed mapping, science investigation, and sub-satellite deployment capabilities...

## Missions SIM Bay Configurations

<table>
<thead>
<tr>
<th>Missions</th>
<th>SIM Bay Configurations</th>
</tr>
</thead>
</table>
| Apollo XV | • Particles and Fields Sub-satellite  
            • Gamma Ray Spectrometer  
            • Mass Spectrometer  
            • Alpha and X-ray Spectrometer  
            • Mapping Camera  
            • Panoramic Camera  
            • Laser Altimeter |
| Apollo XVI | • Lunar Sounder Experiment  
              • UV Spectrometer  
              • IR Scanning Radiometer  
              • Mapping Camera  
              • Panoramic Camera  
              • Laser Altimeter |
| Apollo XVII | • UV Spectrometer  
              • IR Scanning Radiometer  
              • Mapping Camera  
              • Panoramic Camera  
              • Laser Altimeter |
Apollo 15 and 16 Subsatellites

- 36.3 kg, 24 watts
- 78 cm X 36 cm
- 3 instruments
  - Plasma Particles and Magnetic Fields
We Have Successful Flight Precedence:
GSFC’s Hitchhiker, Space Experiment Module,
Get Away Special, and Spartan

- 76 experiments on 26 different Shuttle Flights between 1991 and 2003.
- Low cost, economical, quick turnaround
- Standard interfaces
- Users able to concentrate on their payload while interface with NASA launch vehicle and mission operations organizations completed by GSFC (e.g. manifesting, integration, safety, etc.)
Next, the Shuttle Small Payloads Project (SSPP) developed a process and set of core engineering services for payload to obtain access to low Earth orbit via the Shuttle.

SSPP consisted of a modular, extensible carrier system that supported a wide range of payload sizes and complexities, ranging from 50 to more than 5000 lbs.

SSPP had three mission configurations:

- **Hitchhiker** – payloads requiring power, data and command services
- **Get Away Special** – self contained payloads requiring limited mechanical and electrical interfaces
- **Space Experiment Module** – self contained payloads requiring no Orbiter resources

Nearly 300 secondary payloads flew into space via the Shuttle Small Payloads Project (SSPP) over its 20+ years of operation.
NASA history is rich with examples of secondary payloads, flown through the SSPP capability, making a tangible impact on future NASA efforts to explore our world, solar system and universe…

The Shuttle Laser Altimetry (SLA) technology was adapted for several missions using SLA including the Mars Global Surveyor which topographically mapped 100% of the Martian surface. 

Dr. James Garvin
Chief Scientist, NASA/GSFC
Successful Attached Payload Missions

- Hitchhiker Success Story: Thermal Control Technology – Ted Swanson
- Goddard flew four successive technology experiments using the Shuttle Hitchhiker Program
- Flight experiments were essential to establish proof-of-concept, especially because of the zero-G factor
- Unique Benefits of Shuttle Carrier Program
  - Rapid turnaround – able to mount and fly experiment in as little as 18 months
  - Nominal cost - $2M-$5M per experiment
- Without this Program
  - Would have tried to fly stand-alone experiment on a free-flyer, which is rarely done
  - Would have tried for NMP but that would had much greater cost and required much more time
  - Would not have been able to do successive iterations (which was needed because initial CAPL flight wasn’t successful and CAPL-2 was needed), without which technology wouldn’t have been accepted
- Success
  - Basic ambient temperature two-phase thermal control technology was accepted and is now the baseline for many NASA, DOD, and commercial spacecraft
  - ATK recently reported that they have delivered over 300 flight-qualified two-phase loops, over half of which are now flying.
  - This would not have happened without successful flight experiments, and Hitchhiker was the only really viable way of doing this.
The Constellation Program includes many elements that offer the potential to provide opportunities for science payload capabilities...

Heavy Lift Launch Vehicle – “Ares V” 2018

Earth Departure Stage - 2018

Crew Launch Vehicle – “Ares I” 2014

Crew Exploration Vehicle – “Orion” 2014

Lunar Lander “Altair” - 2018

Dates are approximate and based on current development schedules
Characterizing and Designing the Orion Service Module Accommodations – Orion Unpressurized Carrier

- A triad of payload operational location capabilities and orbits
  - Extracted
  - Fixed
  - Ejected
The Crew Exploration Vehicle - Orion low Earth orbit (LEO) missions to ISS will provide the first opportunity to integrate science payloads into the Constellation architecture...
Ejectable Length $L = 60$ - in

Cylindrical Payload Volume
Ejectable Diameter of $\theta = 50$ - in

Cylindrical Payload Volume
## Lunar Orbit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Capability</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>Lunar</td>
<td>Low thrust - Solar Electric Propulsion Required</td>
</tr>
<tr>
<td>Time to reach Lunar Orbit</td>
<td>15 mo</td>
<td>Includes payload carrier/support hardware and 0.24 m³ Payload Volume</td>
</tr>
<tr>
<td>Stowed Volume</td>
<td>≤2.92 m³</td>
<td>Includes payload carrier/support hardware and 0.24 m³ Payload Volume</td>
</tr>
<tr>
<td>Mass</td>
<td>600 kg</td>
<td>Includes payload carrier/support hardware, with 50 kg Max payload mass</td>
</tr>
<tr>
<td>Power</td>
<td>1.8 kW</td>
<td>100W payload survival heater power required while in Cruise Mode</td>
</tr>
<tr>
<td>Data Rate</td>
<td>≤2.0 Mbps</td>
<td>Higher downlink possible with deployable HGA - Ka-band</td>
</tr>
<tr>
<td>Pointing Accuracy</td>
<td>70 arcsec</td>
<td>3-axis stabilized</td>
</tr>
</tbody>
</table>
Possible UPC Lunar Orbit Configurations

- There are several final orbit configurations possible
- Dependent upon the incoming transfer and B-plane targets
- Two shown below

View towards South Pole

View towards Equator

3-D View

- $a = 7600 \text{ km}$
- $e = 0.7$
- $i = 112^\circ$ (lunar)

- $a = 12670 \text{ km}$
- $e = 0.7$
- $i = 13^\circ$ (lunar)
# LEO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Capability</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>LEO</td>
<td>Only Chemical Propulsion required</td>
</tr>
<tr>
<td>Duration of Flight</td>
<td>0.6 -5 yrs</td>
<td>Depends on orbit</td>
</tr>
<tr>
<td>Inclination</td>
<td>52º</td>
<td></td>
</tr>
<tr>
<td>Stowed Volume</td>
<td>≤2.92 m³(103 ft³)</td>
<td>Includes payload carrier/support hardware and 0.64 m³ Payload Volume</td>
</tr>
<tr>
<td>Mass</td>
<td>600 kg</td>
<td>Includes payload carrier/support hardware and 100 kg Payload.</td>
</tr>
<tr>
<td>Power</td>
<td>200 W</td>
<td></td>
</tr>
<tr>
<td>Data Rate</td>
<td>≤5 Mbps</td>
<td>Higher downlink possible w/deployable HGA or enhanced earth shaped omni using S, X, Ku-, or Ka-band</td>
</tr>
<tr>
<td>Pointing Accuracy</td>
<td>70 arcsec</td>
<td>3-axis stabilized</td>
</tr>
</tbody>
</table>
Fixed Pallet

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Capability</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>LEO, 52°; ~350 km</td>
<td>ISS orbit</td>
</tr>
<tr>
<td>Duration of Flight</td>
<td>180 days</td>
<td>Docked to ISS</td>
</tr>
<tr>
<td>Volume</td>
<td>≤2.92 m³ (103 ft³)</td>
<td>Includes payload carrier/support hardware, 1.02 m³ for a single large payload and 0.26 m³ for each shelf with 4 shelves available</td>
</tr>
<tr>
<td>Mass</td>
<td>Up to 400 kg</td>
<td>Up to 400 kg Max payload</td>
</tr>
<tr>
<td>Power</td>
<td>≤300W</td>
<td>Via Orion SM when docked to ISS</td>
</tr>
<tr>
<td>Data Rate</td>
<td>≤ TBD Mbps</td>
<td>Via to Orion SM when docked to ISS</td>
</tr>
<tr>
<td>Thermal</td>
<td>Passive/Active</td>
<td></td>
</tr>
<tr>
<td>Field of View</td>
<td>Zenith or Nadir</td>
<td>Depends on ISS -Orion dock location</td>
</tr>
<tr>
<td>Payload sites</td>
<td>0ne-Four</td>
<td>Multiple payloads operated sequentially</td>
</tr>
</tbody>
</table>
FRAM (Extractable Payloads)

- Orbit: LEO, 52°; ~350 km
  **Comment:** ISS orbit
- Duration of Flight: Varies
  **Comment:** *Depends on ISS Attached Payload manifest*
- Volume: ≤2.92 m³ (103 ft³)
  **Comment:** Includes payload carrier/support hardware
- Mass: 600 kg
  **Comment:** 400 kg max payload mass based on CMG Study
- Power: 1.25-3.0 kW
  **Comment:** Varies based upon ISS External Payload Attached Site, expect to be unpowered during transfer to the ISS for up to 4.5 hours
- Data Rate: 1.55 - 100 Mbps
  **Comment:** Varies on ISS External Payload Attached Site
- Thermal: Passive/Active
  **Comment:** Use available power for payload provided active thermal control
- Field of View: Zenith or Nadir
  **Comment:** Varies depending upon ISS External Payload Attached Site
Core Capabilities (Lunar Mission)

- Service Module includes an Instrumentation Module (SIM) Bay
  - 0.57 cubic meter volume
  - Capable of holding 382 kg
  - Power and data accommodations
  - Generic provision – specific payloads TBD
Lunar Orbiting and Surface Payloads

Goal
Derived and investigated conceptual designs for exemplary primary science and science support accommodations

- Lunar Telescope
- Lunar Environmental Monitoring Station
- Lunar Unpressurized Cargo Carrier
Conclusions and Follow-On

• Utilizing successful flight models such as Hitchhiker, science payload access to space via Constellation assets will be realizable
• Continued derivation and refinement of designs and concept of operations required
• Science payload needs will directly influence Exploration and Constellation vehicle requirements
• We want your science ideas and inputs