Origins Space Telescope (OST) Mission Concept 1

Open Issues

Face-to-Face #5
June 1-2, 2017

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Concept 1 Design Status/Issues

• Concept 1 mass is ~2,000 kg over the launch vehicle (Vulcan Aces 5m fairing) lift capability
  – Mass for 5 instruments is 2643 kg
    • Far-IR Imager/Polarimeter (FIP): 781 kg
    • High Resolution Spectrometer (HRS): 935 kg
    • Medium Resolution Survey Spectrometer (MRSS): 435 kg
    • Heterodyne Instrument (HI): 383 kg
    • Mid-IR Spectrometer/Imager/Coronagraph (MISC): 108 kg

• Optical ray traces for instruments are still in progress and some are near completion
  – Elimination of any of these instruments will result in rework of ray traces and packaging for remaining instruments

• Fairing volume is extremely tight and uncertain, overall packaging is uncertain and deployment is still TBD

• **Current Concept 1 is too heavy to be launched on a 5m fairing**
  – **Volume is tight and uncertain**
Solution: Larger Launch Vehicle (LV)

- NASA Space Launch System (SLS) has larger mass and volume capabilities to accommodate current OST Concept 1
  - **Fairing Sizes:** 8.4 x 19 m, 10 m x 31 m
- SLS will be available in 2030’s when OST will be ready to launch
  - Both LUVOIR and HabEx mission concepts include SLS
- SLS is a development program and it is yet to have a first launch
  - Higher risk item in mission development
- Larger LV cost will be higher, however larger volume may allow flight system design to be less complex, resulting in lower mission cost overall
Study Office Plan and Request

- Plan to work with instrument teams to scale down instrument volume, mass and power to fit into a 5 meter fairing
- In the event that the scaled down instruments results in exceeding 5m fairing capabilities, we need design flexibility to assume a larger LV
  - In order to complete Concept 1 design by 9/30/17, we need design flexibility

- **Study Office requests STDT permission to go to a larger launch vehicle, if necessary**
  - Need a decision by 6/15/2017, 5pm
## Study Schedule

### Milestone F2F Meetings
- **Jan**: Released 1/26
- **Feb**: F2F #4
- **Mar**: Team X
- **Apr**: Team X
- **May**: Team X
- **Jun**: Team X
- **Jul**: Team X
- **Aug**: Team X
- **Sept**: Team X
- **Oct**: Team X
- **Nov**: Team X
- **Dec**: Team X

### Study Deliverables NASA HQ ApD
- **Telescope System**: Update TRL Assessment Report to HQ (6/30)
- **Far-IR Imager/Polarimeter (HI)**: Update TRL Assessment Report to HQ (6/30)
- **High-Resolution Spectrograph (HRS)**: Update TRL Assessment Report to HQ (6/30)
- **Heterodyne Instrument (MISC)**: Update TRL Assessment Report to HQ (6/30)
- **Mission Definition, Design, & Development**: Update TRL Assessment Report to HQ (6/30)

### Science
- **Define mission requirements, minimum science, science cases**: Address IAM Comments, CR comments, Final report draft and review
- **Define optical requirements for Instrument I/F**: Instrument IDL #1 (8/18)
- **Define mission requirements, science cases for Interim Rpt**: Instrument IDL #1 (8/18)
- **Finalize mission requirements, science cases, science instrument operation scenarios**: Instrument IDL #1 (8/18)

### Technology
- **Decadal Mission Enabling Technology (MRRS)**: Update TRL Assessment Report to HQ (6/30)
- **Far-IR Imager/Polarimeter (FIP)**: Update instrument, requirements, design, interface definitions
- **Far-IR Imager/Polarimeter (FIP)**: Update TRL Assessment Report to HQ (6/30)
- **Far-IR Imager/Polarimeter (FIP)**: Update TRL Assessment Report to HQ (6/30)
- **Mid-IR Imager Spectrometer (MISC)**: Update TRL Assessment Report to HQ (6/30)
- **Mid-IR Imager Spectrometer (MISC)**: Update TRL Assessment Report to HQ (6/30)
- **Mission Definition, Design, & Development**: Refine ETE mission schedule and cost

### Med-Resolution Survey Spectrograph (MRRS)
- **TRL Assessments**: Final Report to HQ
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### Telescope System
- **Telescope System**: Telescope I/D #1 (8/14-18)
- **Telescope System**: Telescope cost estimates review, interface, boundary condition, deployment schemes

### Mission Definition, Design, & Development
- **Mission Definition, Design, & Development**: Mission IDL #1 (9/18-22)
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### Final Deliverables
- **Final Deliverables**: Final Report to Decadal Committee
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OST Concept 1 Design Parameters

- 9 meter diameter primary mirror
  - Segmented, Off-Axis Telescope
- 5 science instruments
  - Far-IR Imager/Polarimeter (FIP)
  - High Resolution Spectrometer (HRS)
  - Medium Resolution Survey Spectrometer (MRSS)
  - Heterodyne Instrument (HI)
  - Mid-IR Spectrometer/Imager/Coronagraph (MISC)
- Instrument Accommodation Module (IAM)
- 8 cryo-coolers to cool and maintain Telescope and IAM at 4 Kelvin
- Launch on a 5 meter fairing launch vehicle
  - Vulcan Aces assumed
- Mission Operations Orbit is Sun Earth L2
5m Fairing Design Challenges

1. Mass exceeds allowable.
2. Stowing and deploying Sunshade and Baffle:
   - Might be enough space to do it in current configuration – TBD. Stowed stack-up only allows for .75m in height for stowing Sunshade.
   - Engineer, with in-depth knowledge of JWST Sunshade design, is just starting to look at it.
   - Cable harnesses and cryo lines (volume TBD) need to stow in same area as Sun Shade. May not be enough room for it all.
   - How to deploy the cable harnesses and cryo lines AND the Sunshade when they all stow in same location may be unworkable.
   - May not be enough room in bus to store everything. Many deployment booms are needed for Sunshade. Large prop tank takes up a lot of room, as well. Layout of Bus is TBD.
3. Currently HRS instrument interferes with lower corner of stowed Primary Mirror
   - Packaging of HRS might not allow for removal of interference – TBD.
   - Removing one hex segment of PM required if HRS interference remains.
4. CG if stowed assembly will be rather high. High CG and high mass may preclude using this launch vehicle.
Layout shown is a bit obsolete, but the .75m space is accurate, given current launch vehicle fairing limitation.
Area of red triangle $= \frac{1}{2}[(142-57)/2]^2 = 903 \text{ in}^2$

Area of DTA $= \pi \times D^2/4 = \pi \times 40 \text{ in}^2/4 = 1256 \text{ in}^2$

Area of bus top shape without DTA area $= 142^2 - 4(903") - 1256 = 20,164 \text{ in}^2 - 3,612 \text{ in}^2 - 1256 \text{ in}^2 = 15,296 \text{ in}^2$ ($9.8 \text{ m}^2$)

Volume available for sunshade stowage and cable harnesses and cryo lines $= 9.8 \text{ m}^2 \times 0.75 \text{ m} = 7.35 \text{ m}^3$
# Concept 1 Mass Estimates

preliminary and immature

<table>
<thead>
<tr>
<th>Item</th>
<th>Mass Estimate (kg)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruments (Total of 5)</td>
<td>2,370</td>
<td>Initial allocation total of ~825 or ~165 kgs per instrument</td>
</tr>
<tr>
<td>FIR Imager/Polarimeter (FIP)</td>
<td>508</td>
<td>Initial IDL mass estimate with OST Team Modifications</td>
</tr>
<tr>
<td>Hetrodyne Instrument (HI)</td>
<td>383</td>
<td>Martina's Rough Estimate</td>
</tr>
<tr>
<td>High Resolution Spectrometer (HRS)</td>
<td>936</td>
<td>Initial IDL's mass estimate</td>
</tr>
<tr>
<td>Medium Resolution Survey Spectrometer (MRSS)</td>
<td>435</td>
<td>Initial Rough Estimate provided by JPL</td>
</tr>
<tr>
<td>MID-IR Imager Spectrometer Coronograph (MISC)</td>
<td>108</td>
<td>Initial estimate from Itsuki Sakon, March 2017 F2F meeting</td>
</tr>
<tr>
<td>Optical Telescope Element (OTE)</td>
<td>2,594</td>
<td>Assumes 40 kgs/m², unknown if possible, dependant on material selected and needed OTE structural frequency. The JWST figure is ~68 kgs/m² all inclusive (see OTE Tab).</td>
</tr>
<tr>
<td>Cryocoolers (8 @ 66 kgs each)</td>
<td>528</td>
<td>Mike Dipirro's Mass Estimate</td>
</tr>
<tr>
<td>20 K Box</td>
<td>TBD, ~10's of kilograms, relatively small</td>
<td>Mike Dipirro's Mass Estimate</td>
</tr>
<tr>
<td>Sunshield</td>
<td>1,000</td>
<td>Rajeev Sharma's mass estimate (Drew Jones' initial rough estimate was 1,861 kgs)</td>
</tr>
<tr>
<td>Baffle Assembly</td>
<td>350</td>
<td>Rajeev Sharma's mass estimate (Drew Jones' initial rough estimate was 223 kgs)</td>
</tr>
<tr>
<td>IAM (Less Instruments)</td>
<td>321</td>
<td>Greg Martin's Rough Estimate</td>
</tr>
<tr>
<td>SC Bus</td>
<td>2,284</td>
<td>Anel &amp; Greg Martin's Rough Estimate</td>
</tr>
<tr>
<td>Deployable Tower Assembly (DTA)</td>
<td>149</td>
<td>Greg Martin's Rough Estimate</td>
</tr>
<tr>
<td>Current Best Estimate (CBE) Dry Mass</td>
<td>9,596</td>
<td></td>
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<tr>
<td>Propellant/ Pressurant</td>
<td>1,360</td>
<td>Based on a projected ~200 m/s Delta V, Folta and Webster; or ~960 kgs; plus ~400 kgs for momentum unloading, Eric Stoneking. Assumes MPV mass of 11, 095 kgs.</td>
</tr>
<tr>
<td>Current Best Estimate (CBE) Wet Mass</td>
<td>10,956</td>
<td>Ideally ~9,015 kgs or below</td>
</tr>
<tr>
<td>CBE Wet Mass Overweight</td>
<td>1,941</td>
<td></td>
</tr>
<tr>
<td>Contingency (%)</td>
<td>23.1%</td>
<td>Estimated effective contingency needed based on CBE Dry mass only</td>
</tr>
<tr>
<td>Contingency (kgs)</td>
<td>2,215</td>
<td>Estimated effective contingency needed based on CBE Dry mass only</td>
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<tr>
<td>Maximum Expected Value (MEV) Dry Mass</td>
<td>11,810</td>
<td></td>
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<tr>
<td>Maximum Expected Value (MEV) Wet Mass</td>
<td>13,170</td>
<td>Needs to be below ~11,095 kgs</td>
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<tr>
<td>MEV Wet Mass overweight</td>
<td>2,075</td>
<td></td>
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</table>
## Potential Launch Vehicles

<table>
<thead>
<tr>
<th>Launch Vehicle</th>
<th>Manufacturer</th>
<th>Country of Origin</th>
<th>Cost per launch</th>
<th>Fairing Size Dia. by Length</th>
<th>Payload to GTO (kg)</th>
<th>Payload to L2(2)</th>
<th>Status</th>
<th>Launch Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U.S.A./ Active</strong></td>
<td></td>
<td></td>
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<tr>
<td>Delta IV Heavy</td>
<td>ULA</td>
<td>U.S.A.</td>
<td>$375 Million (2014)</td>
<td>5 m x 19.1 m</td>
<td>14,220</td>
<td>10,695</td>
<td>Active</td>
<td>SLC-37B, Cape Canaveral SLC-6 Vandenberg AFB</td>
</tr>
<tr>
<td>Atlas V 500 Series</td>
<td>ULA</td>
<td>U.S.A.</td>
<td>Not Available</td>
<td>5.4 m x 20.7 m / 5.4 m x 23.5 m</td>
<td>4,750 – 8,900</td>
<td>2125 - 6,165</td>
<td>Active</td>
<td>Cape Canaveral SLC-41, Vandenberg AFB SLC-3E</td>
</tr>
<tr>
<td><strong>U.S.A./ In development</strong></td>
<td></td>
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</tr>
<tr>
<td>Falcon Heavy</td>
<td>SpaceX</td>
<td>U.S.A.</td>
<td>$90 Million for up to 8,000 kg to GTO</td>
<td>5.2 m x 13.1 m</td>
<td>(27°) 22,200</td>
<td>Not Available</td>
<td>In development</td>
<td>Kennedy LC-39A, Vandenberg AFB SLC-4E</td>
</tr>
<tr>
<td>Space Launch System</td>
<td>Boeing, ULA, Orbital ATK, Aeroject Rocketdyne</td>
<td>U.S.A.</td>
<td>$500 Million</td>
<td>5 m x 19 m / 8.4 m x 19 m / 10 m x 31 m</td>
<td>Not available</td>
<td>Not Available</td>
<td>In development</td>
<td>LC-39B, Kennedy Space Center</td>
</tr>
<tr>
<td><strong>Foreign/ Active</strong></td>
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<tr>
<td>Ariane 5</td>
<td>Airbus Defense and Space</td>
<td>Europe</td>
<td>$165 - $220 Million (20 ESA member states)</td>
<td>5.4 m x 17 m</td>
<td>(27°) ECA(5): 10,500</td>
<td>Not Available</td>
<td>Active</td>
<td>Guiana Space Centre ELA-3, French Guiana</td>
</tr>
<tr>
<td>H-IIB</td>
<td>Mitsubishi Heavy Industries</td>
<td>Japan</td>
<td>Not Available</td>
<td>5.1 m x 15 m</td>
<td>8,000</td>
<td>Not Available</td>
<td>Active</td>
<td>Tanegashima Space Center, Japan</td>
</tr>
</tbody>
</table>

### Notes:

1. FT – Full Thrust is the latest version of the Falcon 9; versions v1.1 and v1.0 are retired from service.
2. ECA - The Ariane 5 ECA (Evolution Cryotechnique type A), first successfully flown in 2005, uses an improved Vulcain 2 first-stage engine with a longer, more efficient nozzle with a more efficient flow cycle and denser propellant ratio. The Ariane 5 ECA has a GTO launch capacity of 9,100 kg (20,100 lb.) for dual payloads or 9,600 kg (21,200 lb.) for a single payload. ES - the Ariane 5 ES (Evolution Storable) has an estimated LEO launch capacity of 21,000 kg (46,000 lb.). Ariane versions A5 G, A5 G+, and A5 GS are retired from service.
3. L2 - Lagrange point 2 named after Joseph Lagrange, an 18th century mathematician, who found the solution to the “three-body problem”. In astrodynamics, the characteristic energy ($C_3$) is a measure of the excess specific energy over that required to just barely escape from a massive body. The units are length²/time², i.e., energy per mass. In this case an initial $C_3$ estimate of -0.5 km²/sec² to L2 was assumed.
4. Assumes the Drone recovery option for the Falcon 9 FT 1st Stage and launch from SLC-41 at CCAFS.