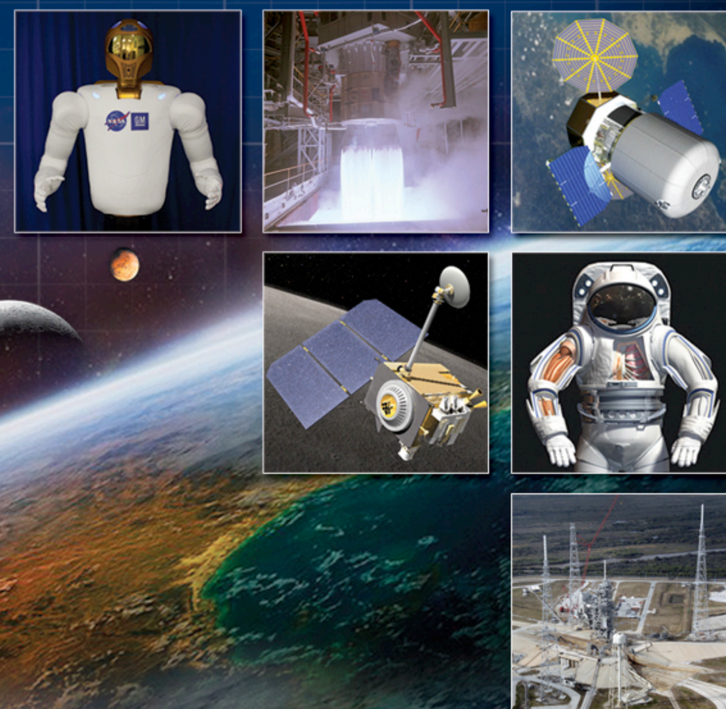
National Aeronautics and Space Administration

Flagship Technology Demonstrations:

CRYOGENIC Propellant STorage And Transfer (CRYOSTAT) Mission



Stephan Davis/MSFC

May 2010

Disclaimer

- This chart set was presented on May 26, 2010 at the NASA Exploration Enterprise Workshop held in Galveston, TX. The purpose of this workshop was to present NASA's initial plans for the potential programs announced in the FY2011 Budget Request to industry, academia, and other NASA colleagues. Engaging outside organizations allows NASA to make informed decisions as program objectives and expectations are established.

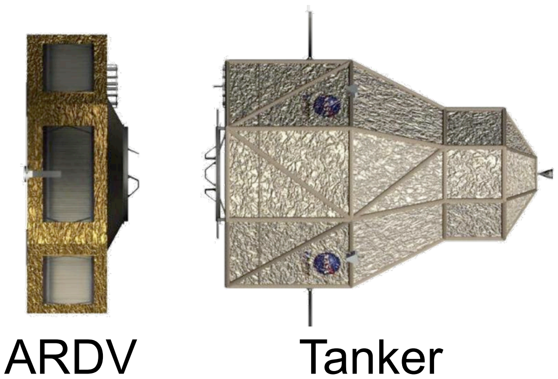
- The following charts represent at "point of departure" which will continue to be refined throughout the summer and the coming years. They capture the results of planning activities as of the May 25, 2010 date, but are in no way meant to represent final plans. In fact, not all proposed missions and investments fit the in budget at this time. They provide a starting point for engagement with outside organizations (international, industry, academia, and other Government Agencies). Any specific launch dates and missions are likely to change to reflect the addition of Orion Emergency Rescue Vehicle, updated priorities, and new information from NASA’s space partners.

CRYOSTAT Mission

- Mission Objectives
  - Demonstrate in-space cryogenic fluid management systems
  - Demonstrate in-space propellant transfer
  - Demonstrate cryogenic-liquid engine in-space thrust-on-need.
  - Demonstrate Automated/Autonomous Rendezvous and Docking

- Approach
  - Critical technologies are demonstrated in one mission utilizing two vehicles
    - Passive tanker for intra-vehicular propellant transfer
    - Active service vehicle for automated rendezvous & docking and propellant transfer from the tanker

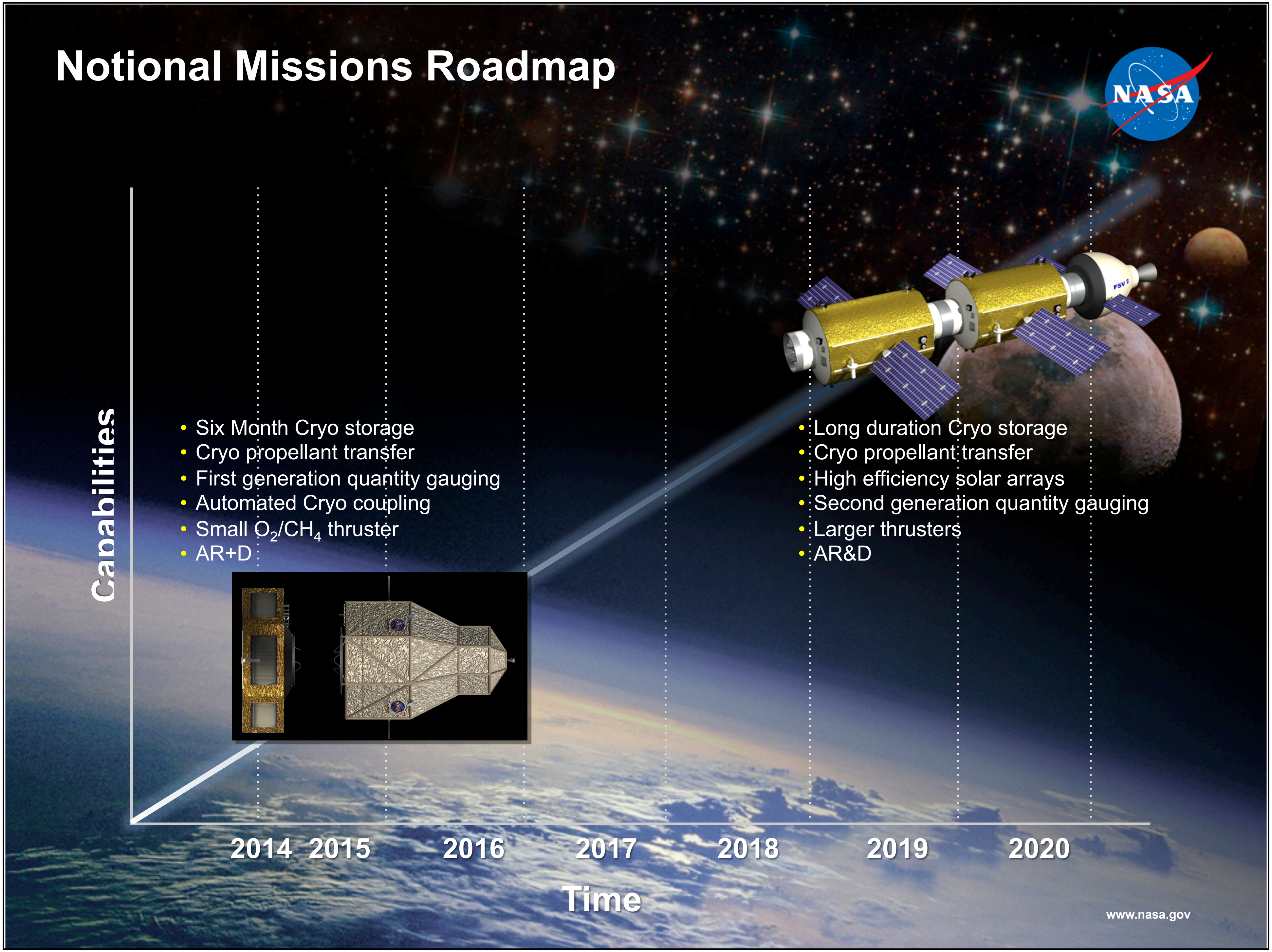
- Key Mission Milestones:
  - Start-up 2011
  - Mission launched in 2015
  - Mission Duration: One year



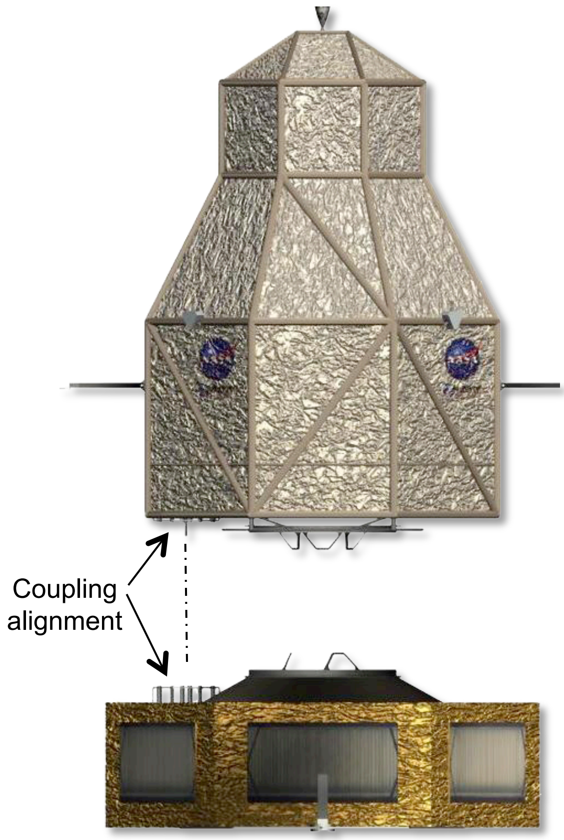
Point of Departure (POD) Concept

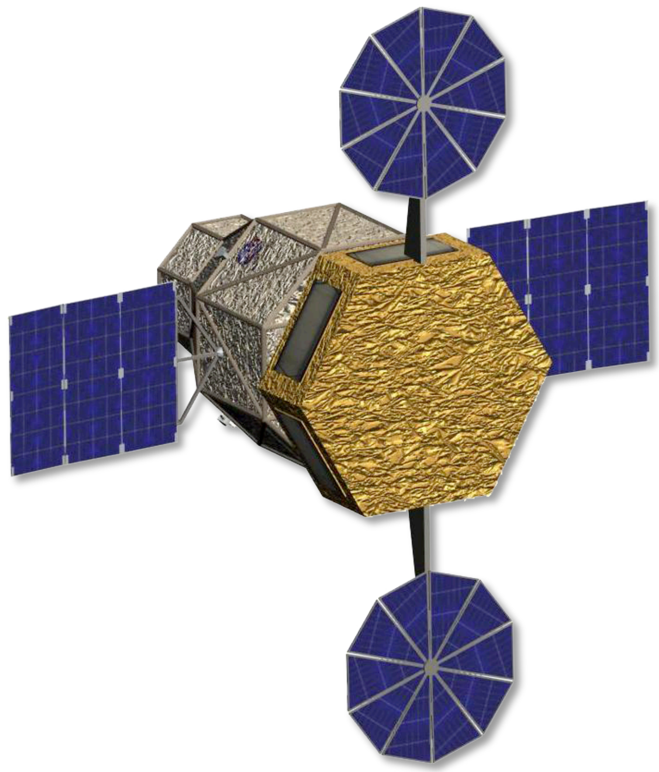
Mission Primary Objectives

Objectives: Demonstrate…	Need for In Space Demonstration
… "long term" <u>storage</u> of cryo propellants	• Susceptibility to heating (boil-off) and thermal control of cryogens can only be demonstrated and quantified in low-g.
… <u>transfer</u> of cryogenic propellants	• Low-gravity thermodynamic and fluid behavior (e.g., surface tension effects, transport heat losses, etc.) can only be demonstrated and quantified in space.
… automated or robotic physical <u>connections</u> between cryo propellant lines	• Remote transfer line/tank/coupling leak checking, pre-conditioning, and purging behavior is different in low-g.
… ability to verify cryo propellant <u>acquisition</u>, withdrawal and transfer	• Gravity force in 1-g can overwhelm surface tension forces used for acquisition in low-g. • Demonstrate measurement of cryogenic tank liquid mass in low-g.
AR&D	• Perform integrated demonstration of AR&D technologies with propellant transfer in a relevant environment.


Notional Missions Roadmap
NASA
Capabilities
- Six Month Cryo storage
- Cryo propellant transfer
- First generation quantity gauging
- Automated Cryo coupling
- Small O_2/CH_4 thruster
- AR+D
- Long duration Cryo storage
- Cryo propellant transfer
- High efficiency solar arrays
- Second generation quantity gauging
- Larger thrusters
- AR&D
2014 2015 2016 2017 2018 2019 2020
Time
www.nasa.gov

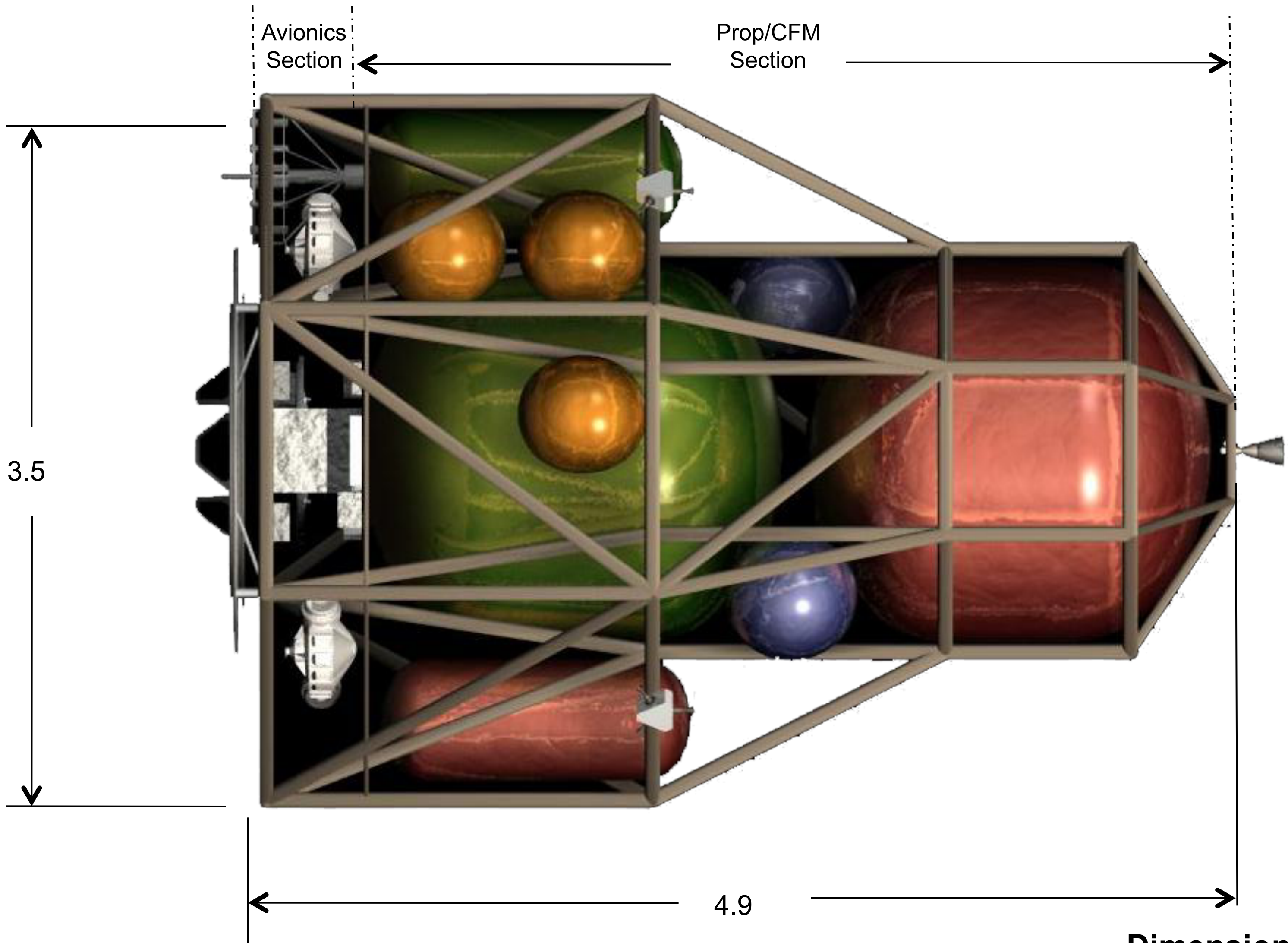
POD ADV & Tanker





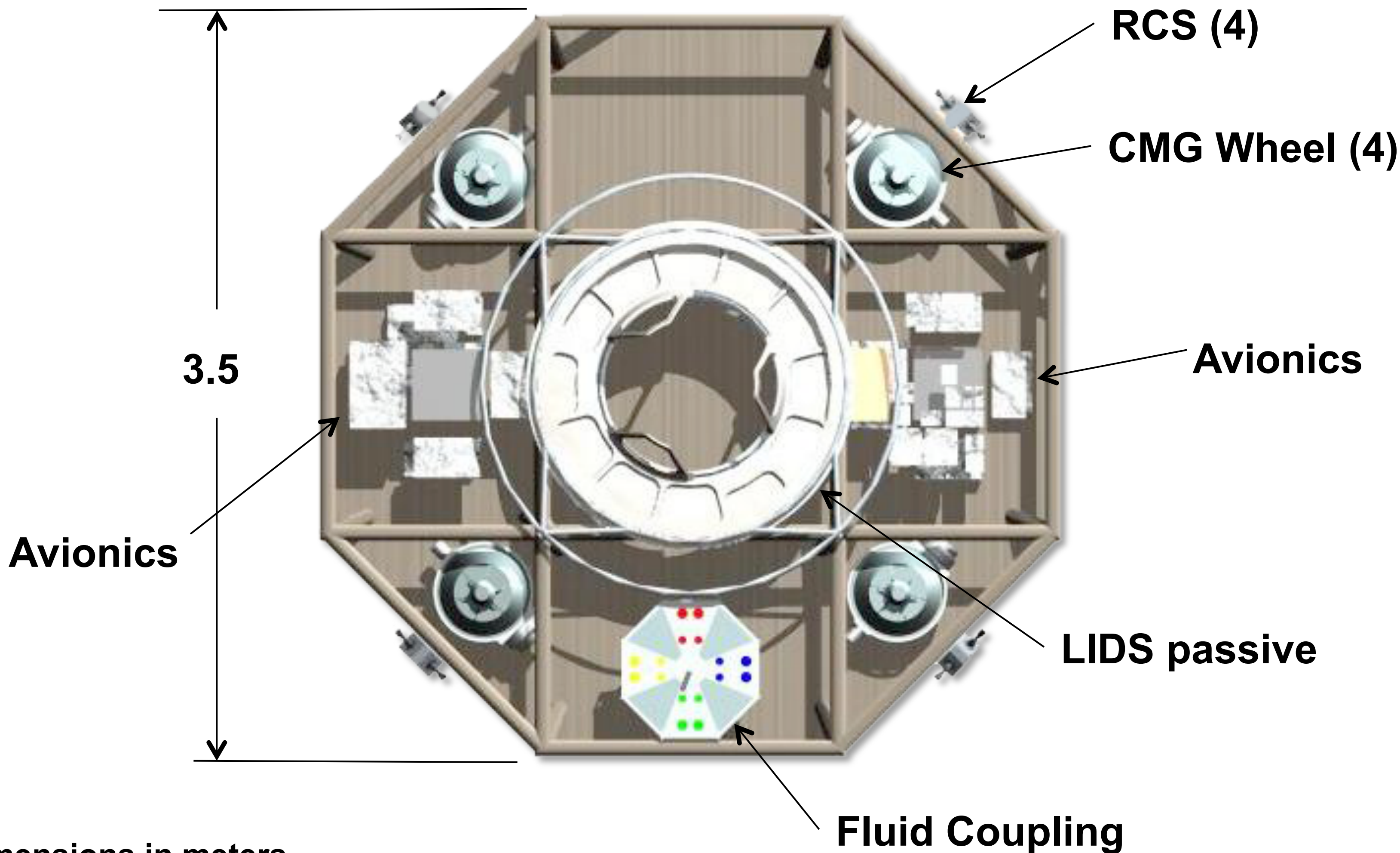
POD Launch weight ~ 16mT

POD Internal Layout



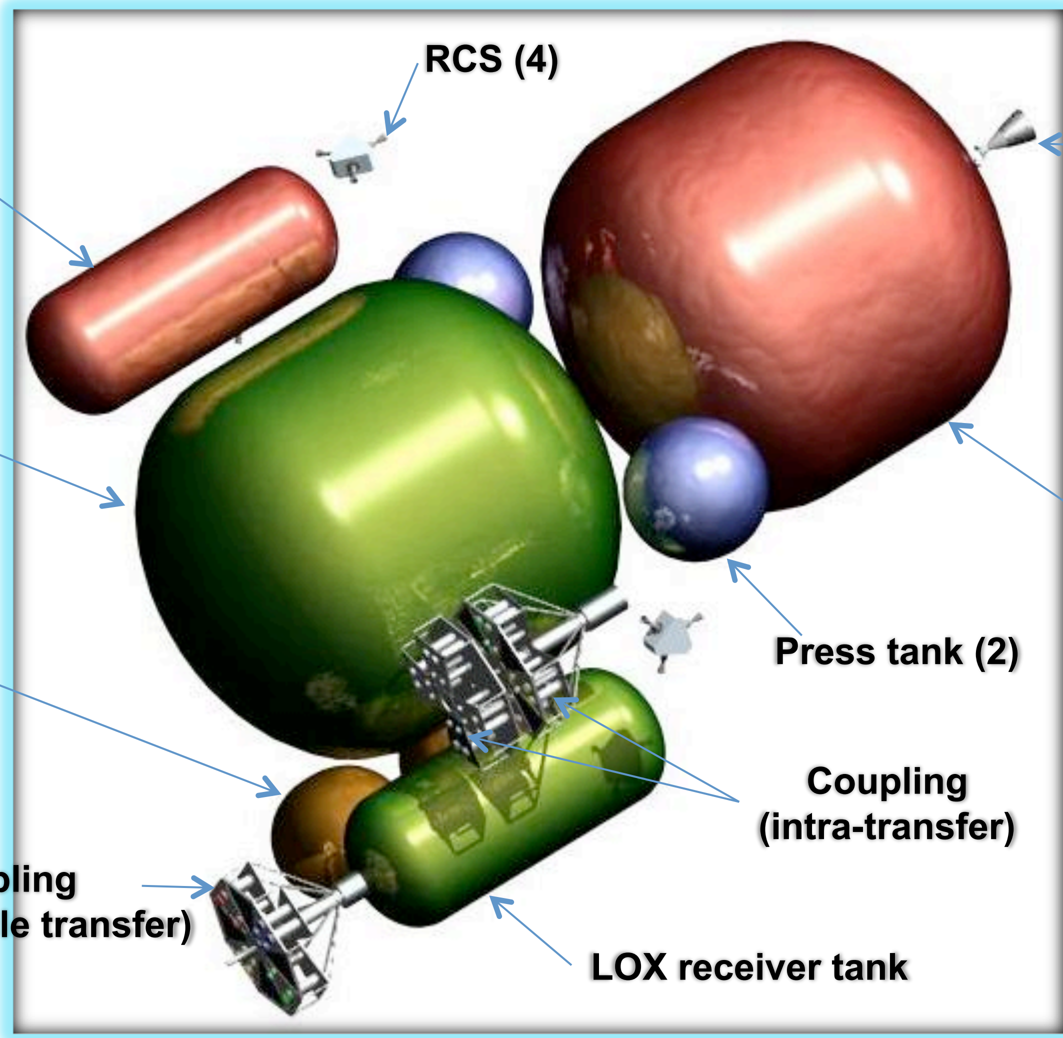
Dimensions in meters

POD Docking Interface

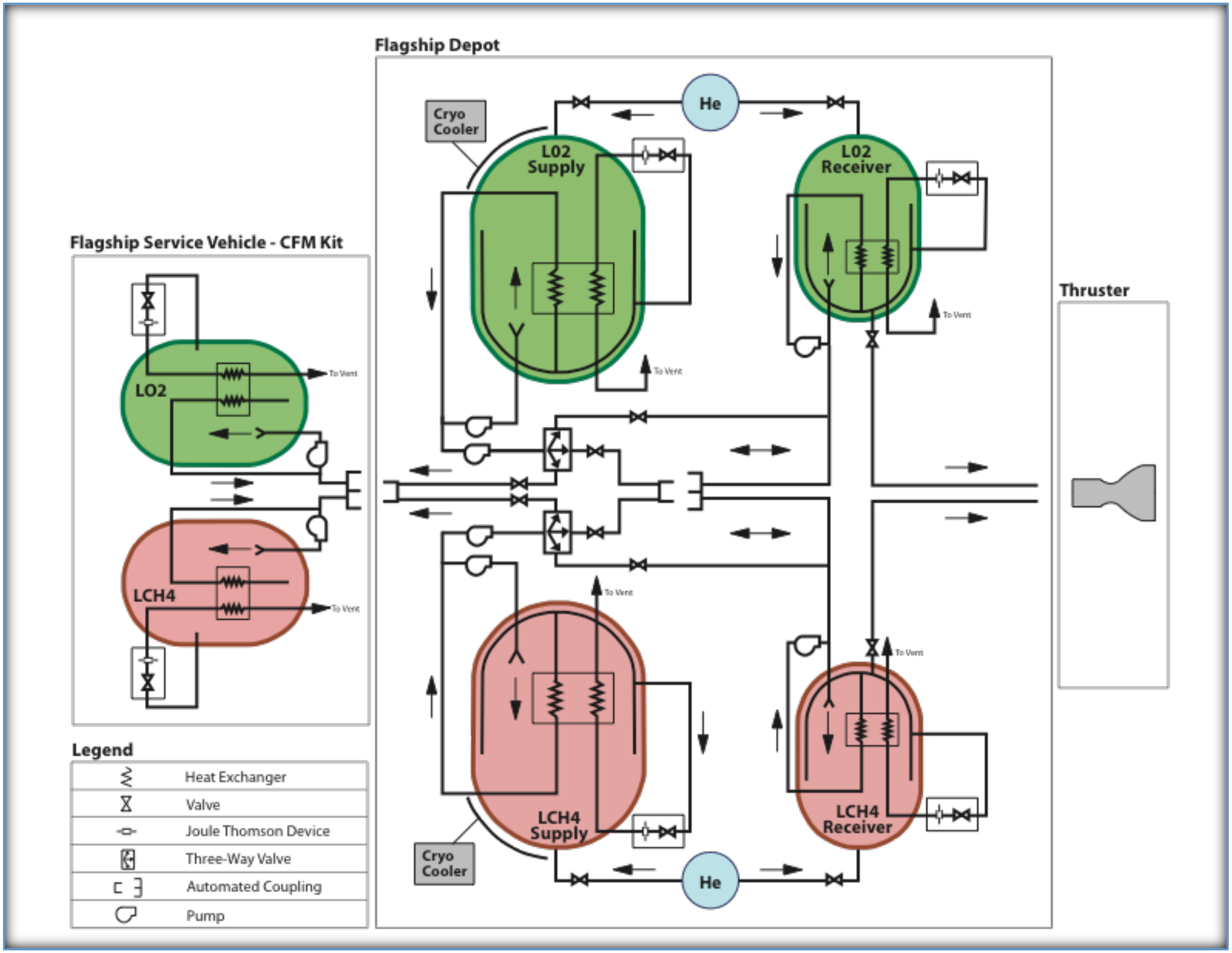


Dimensions in meters

CFM System Components



POD CFM System Schematic



POD CFM Technology

- **Long-term storage of LOX/LCH4**
  - Thermodynamic vent system (passive CFM)
  - Cryo-coolers with tube-on-tank heat collection (active CFM)
- **Intra-vehicular LOX/LCH4 transfer**
- **Inter-vehicular LOX/LCH4 transfer**
- **Liquid acquisition in zero-g**
- **Mass gauging**
- **Propellant conditioning during transfer**
- **Transfer rate measurement and vapor detection**
- **Leak detection**
- **Automated fluid coupling**
- **Low-conduction structural concept**

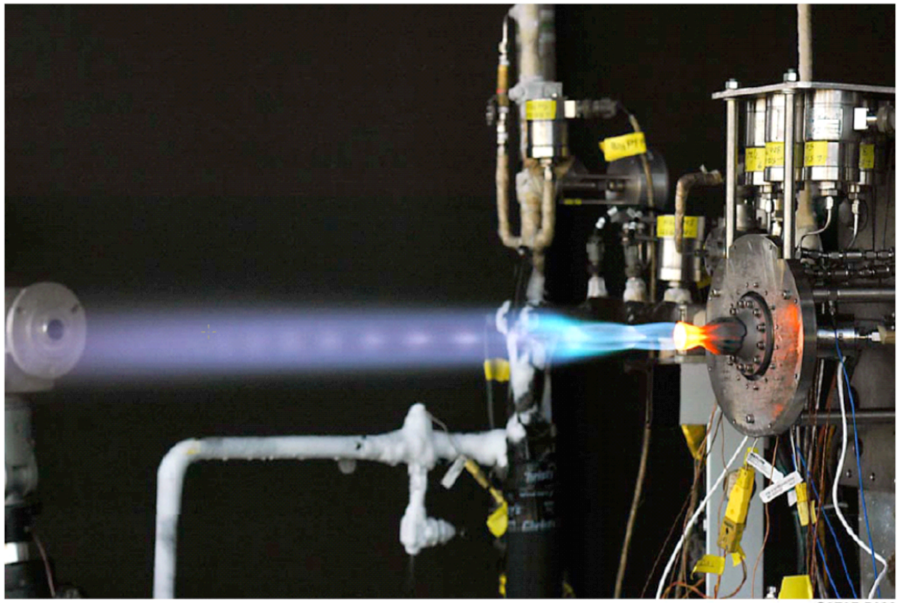
Cryo-cooler

Liquid Acquisition Device

POD LOX/Methane Thruster Technology

- Demonstration Thruster:
  - 100 lbf thrust class
  - Pressure-fed

- Planned Demonstrations
  - Steady-start burns
  - Pulse tests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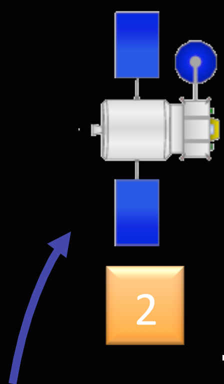
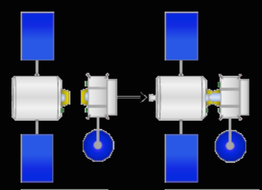
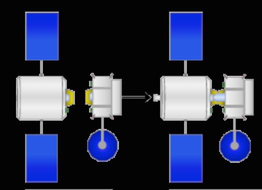
POD Notional Mission Profile

Mission Year (Months)											
1	2	3	4	5	6	7	8	9	10	11	12

Intra-vehicular CFM Demos	AR&D Demonstrations







Mission Sequence

1. Tanker and ADV Launched on ELV
   (Connected by separable payload connector)
2. Tanker Performs Intra-Vehicular CFM Demos and LOX/Methane Thruster Demos
3. Tanker Perform Inter-Vehicular Prop Transfers
4. Tanker Performs AR&D Demos
   (FSD continues active and passive CFM demos)
5. Tanker Performs Final Docking With FSD
6. Tanker de-orbits the combined spacecraft

Enabling Technologies

- "Long-duration" in-space missions will be enabled/enhanced by CFM and transfer due to **increased performance** of propellants.
  - LOX/LCH4, LOX/LH2 ISPs (~335 – 460 sec.) while storables ISP (~240 – 300 sec.)
  - Minimizes propellant load for a given mission.
  - Enables eventual use of In Situ Resource Utilization (ISRU) propellants for lunar or Mars missions.

- In-orbit transfer of propellants allows space vehicles to be refueled on-orbit.
  - May **reduce launch vehicle weight** due to P/L being flown dry or reduced prop
  - Enables commercial providers to deliver on-orbit propellants.
  - Enables on-orbit assembly, satellite servicing missions, and resupply or empty or partially filled stages and spacecraft.

- Provides **operational benefits**
  - Provides path for eliminating hazardous and environmentally harmful hypergolic propellants.
    - Improves ground handling (e.g., tanking) operations.

Enhancing Benefits of Early Development

- Architectures will not baseline long-term in-space cryogenic storage and transfer until the technology is mature, but the technology will not mature unless a demonstration is done - which usually requires an architecture to need it. [Catch 22].

- Long term architectures for earth departure missions will be based on proven technologies and approaches.
  – Risk must be reduced to an acceptable level to be considered reasonable.
  – Tanker decision will impact vehicle sizing and must be addressed prior to PDR.

- To encourage commercialization, NASA should complete the in-space cryogenic propellant transfer and storage technology demonstration.

Cryogen Options Review: Why Methane (vs. Hydrogen)

- A early LOX/Methane demo offers advantages:
  - Enables methane-based systems and mitigates risks for LH2 systems.
  - Allows direct comparison of active vs. passive cooling.
  - Leverages recent investments in LO2/LCH4 cryo fluid management
  - Leverages recent investments in pressure-fed engines
  - Breaks the barrier for long-duration cryo systems.

Cryo Temps		
LCH4:	112	K
LO2	90	K
LN2	77	K
LH2	20	K

- A LOX/Hydrogen demo in foreseeable future is possible.
  - Low cryo cooler TRL implies shorter mission duration.
  - No accurate gauging method for unsettled propellants.

- Due to similarity of LOX and LCH4 properties (e.g. temp, density, etc.), the same components <u>may</u> be qualified and used for ground test and flight hardware.

RFI: (General) Responders Information

1. Responses are due by 5:00 PM EDT on June 11, 2010
2. Use NSPIRES to upload responses
3. Responses are limited to 10 pages

- On the cover page -
    1. RFI Solicitation Number and Title
    2. Responding Organization (including address, POC and phone number)
    3. A brief synopsis of the RFI response in less than 20 words
    4. Section number your response is addressing
    5. Potential partnerships (industry, international, US government agencies)
    6. Whether your company/organization would be available for a site visit

RFI – (CRYOSTAT) Question Areas

1. General/Programmatic

2. Precursor Technology/Analysis Develop./Trade Studies

3. Ground/Launch Operations

4. On-Orbit Operations

RFI – (CRYOSTAT) Information Requested Guidance

- Flight architecture (cryogen transfer) recommendations (options)
  - Stand-alone vehicle providing intra-vehicular transfer
    - » AND/OR
  - Separate vehicles providing inter-vehicular transfer

- Technologies information should include:
  - Maturity level (heritage with supporting evidence),
  - Estimate the level of investment, lead time, and difficulty (risk) needed to advance the technology to flight–ready status

- Risk mitigation strategies to ensure demonstration vehicle integration can occur in FY14, supporting a launch in late FY15.

- Identify capabilities and qualifications which provide expertise relevant to the aspects of the mission (architecture, sub-systems, components, con-ops, ground ops, etc.)

Contact Information

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