Small Spacecraft Systems Engineering & Integration

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Small Spacecraft

Key Features

- Low mission costs ($50-100M), short schedule <24 months
- Low mass < 300kg, low cost launch vehicles

Benefits

- Lower cost enables increased number of missions
- Faster learning cycle, leads to lower costs
- Demonstrate new technology sooner, lowers cost of large missions
- Lower overall program risk by providing several flight opportunities for critical experiments
- Smaller teams, fewer interfaces, improved collaboration

Drawbacks

- Size, mass eliminate some missions for small spacecraft
- Higher individual risk of missions compared with $1B spacecraft
- Use of “yet to be proven” launch vehicles, or fly as a secondary payload

Mission Requirements

Mission Requirements

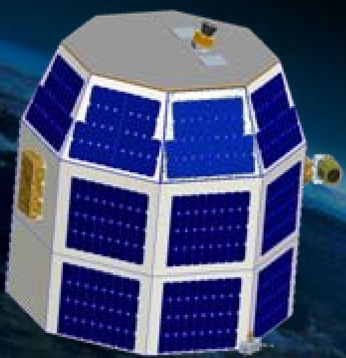
- Spacecraft to be compatible with either Falcon-1 or Minotaur V launch vehicle
  - Critical mass and volume constraints derived from Falcon-1 LV
- Mission durations:
  - Orbiters: 1 Year in Earth or lunar orbit
  - Landers: operational during one lunar day (14 earth days)
- Spacecraft design to be *modular* to support multiple configurations

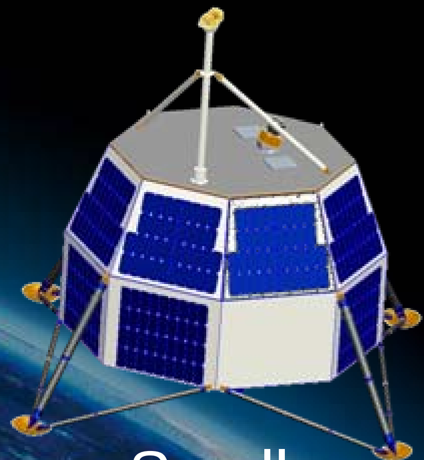
Mission Requirements

- Lander specific requirements:
  - Designed for either equatorial or polar landings
  - Descent landing requirements
    - Lander slope requirements – up to 15 degrees
      - Based on lunar surveyor landing data
    - Lander Horizontal velocity requirements < 1 m/sec (TBR)
      - Trade between GNC performance and lander stability
    - Lander vertical velocity requirements – up to 3- 4 meters for engine cutoff (TBR)
    - Lander obstacles – 10 cm min, up to 25 cm desired(TBR)
    - Lander accuracy – 1 km, 1s baseline, precision landing (TBR)

Common Spacecraft Bus – Modular Approach

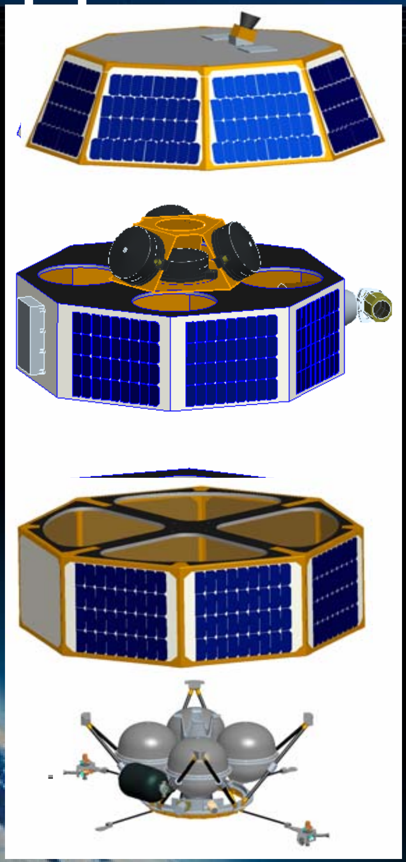
Orbiter





Small Lander

Featherweight Lander

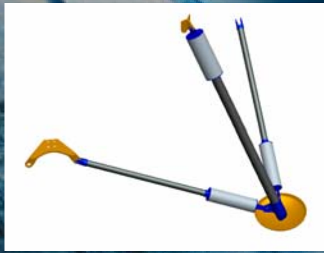


Bus Module

Payload Module

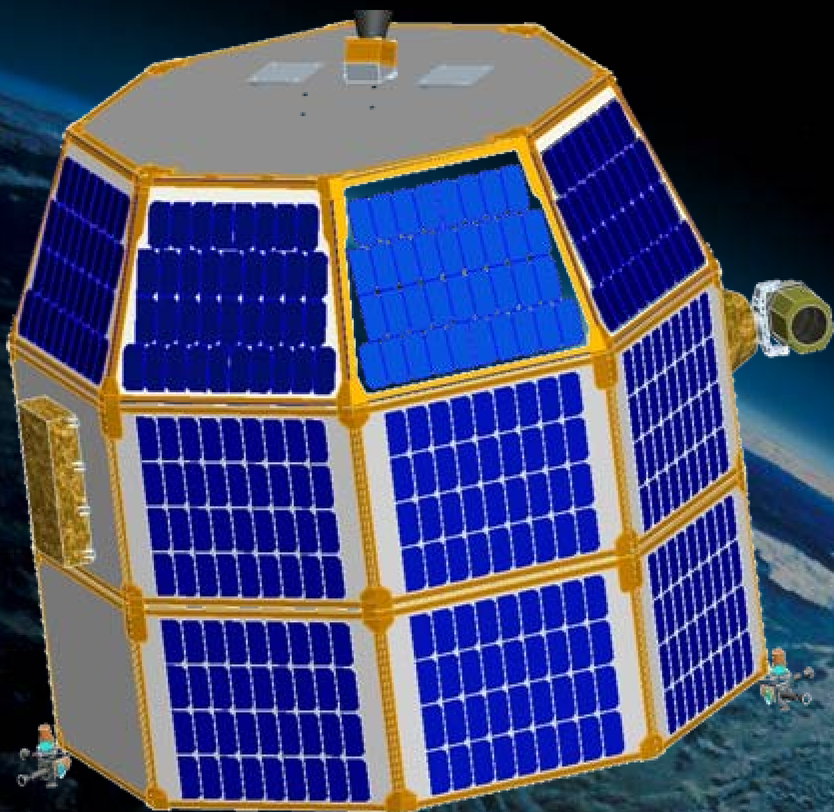
Extension Module

Propulsion Module



- Legs

Orbiter Configuration



Bus Module

Payload Module

Extension Module

Propulsion Module

Laser Communications Orbiter

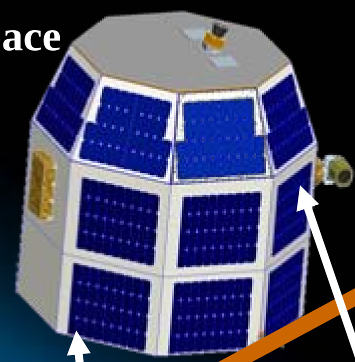
Laser Communication
Data rate: 100 Mbps down 10Mbps up
Mass: 30 lbs (~13.6 kg)
Power: 30 W
Aperture: 3.5 cm
Pointing required: 1-10 arc sec

UHF Selectable Radio
Data rate: 4 Mbps up/down
Mass: 3 kg
Power: 60 W Input, 10W output

Mission Phases
- Launch TLI, early orbit check out
- Cruise
- Lunar orbit
- Lunar relay

Space Segment

Comm data from Cis lunar space



Spacecraft
- Derivative of existing spacecraft
- Single string
- Spaceframe structure
- Zero momentum-biased control design
- Stellar-based attitude determination
- Body-fixed GaAs solar arrays
- cPCI-based C&DH design
- SGLS SOH/Cmd , 1 Mbps downlink,

Mission Operations
- Mission scenarios, timelines, & CONOPS
- Space vehicle flight Ops at ARC
- Payload data processing at GSFC
- Supports continuous operations of payloads
- SV Mission operations from MOC
- Data routed to external users
- Uplink/downlink communications encrypted

LAUNCH SEGMENT

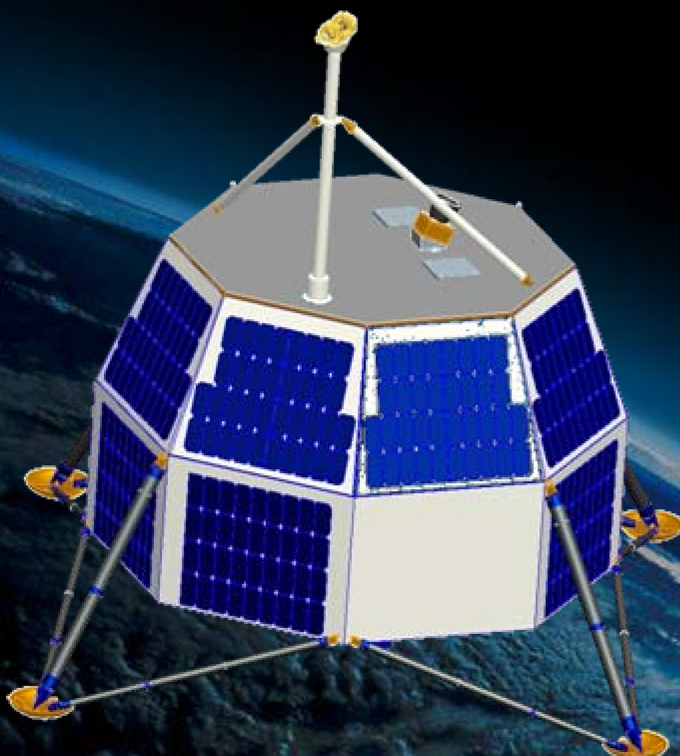
GROUND SEGMENT

Launch Vehicle
- Minotaur V Launch System
- Wallops island (WFF) launch Site
- 30 Day launch processing schedule
- 2009 launch

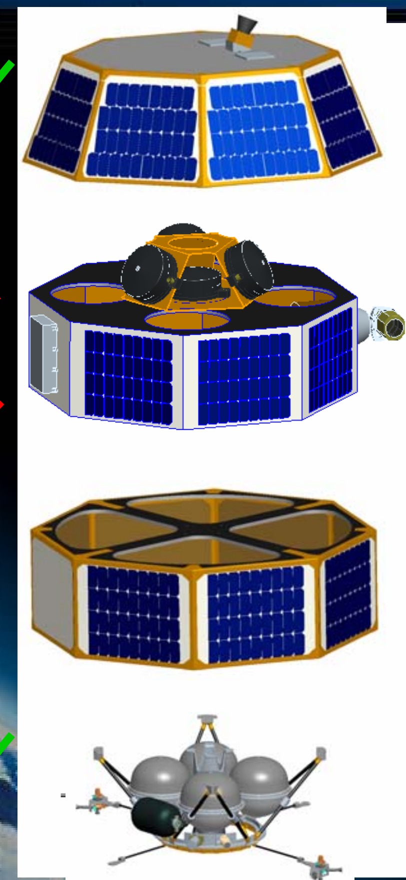
Ground System

Command and telemetry, payload data

Small Lander Configuration



- Baseline/Small Lander



Bus Module

Payload Module

Extension Module

Propulsion Module

- Legs

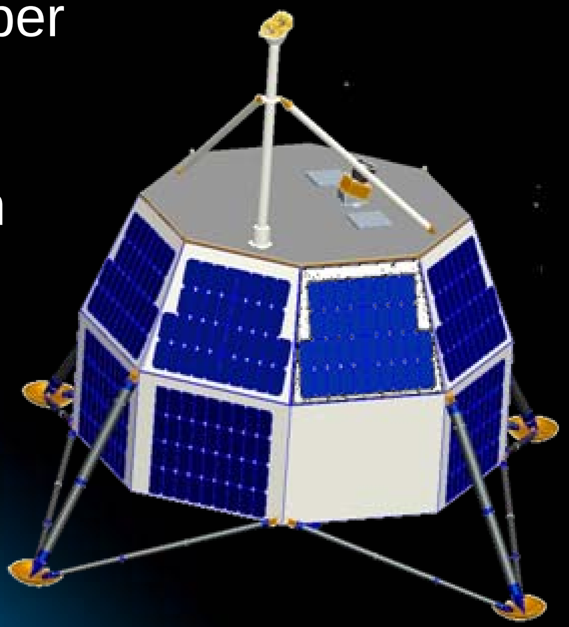
Lunar Lander Missions

Objective:

- Initiate a series of small Lunar lander missions beginning by 2008 with a budget of $100M per mission including launch vehicle.

Goals:

- Achieve a robust robotic precursor program
- Help sustain the vision
- Enable training of our systems engineers
- Reduce costs to program
- Answer critical questions for Constellation



Current capabilities support two nearly identical designs:

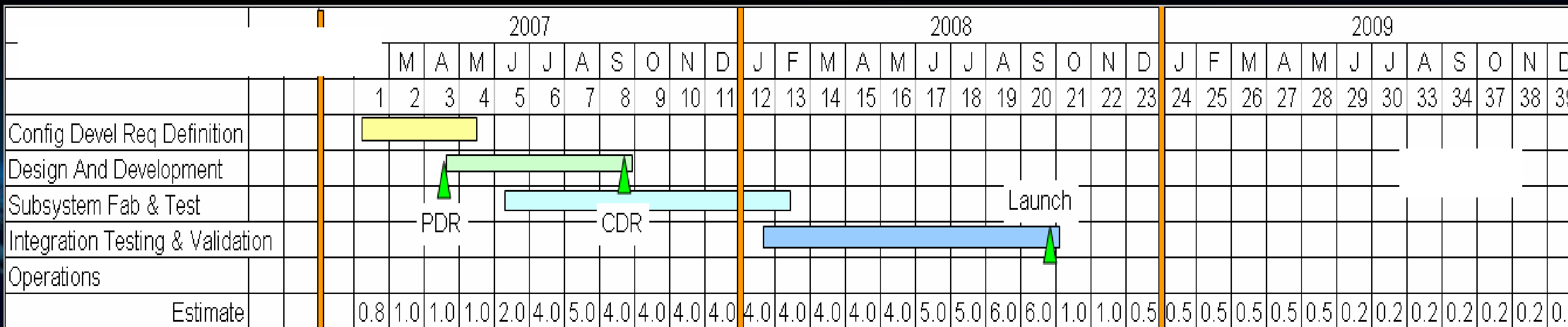
- 130 Kg Lander (four tanks) on a Minotaur V
  - 40 Kg science payload to surface, 200 Watts
- 103 Kg Lander (two tanks) on a Minotaur V
  - 15 Kg science payload to surface, 100 Watts
- 55Kg Lander (two tanks) on a Falcon 1

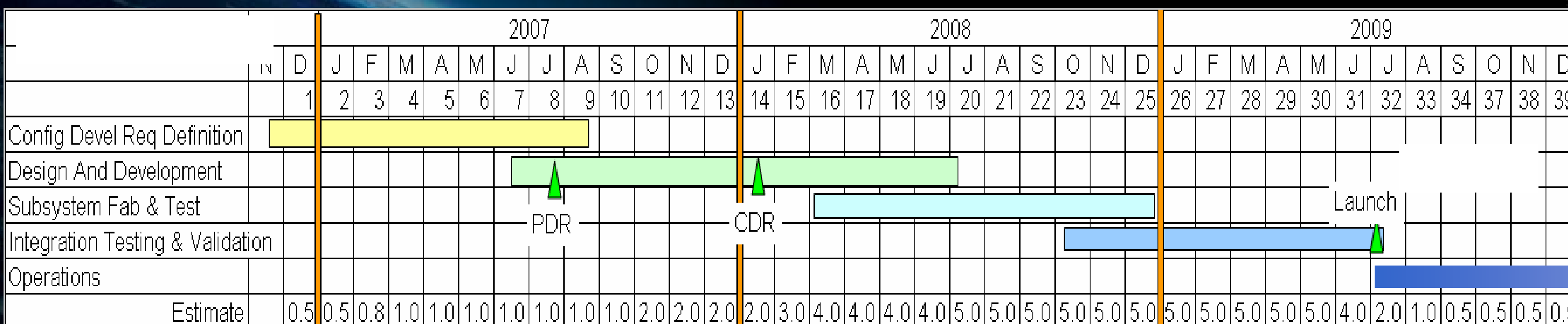
Lunar Lander Missions

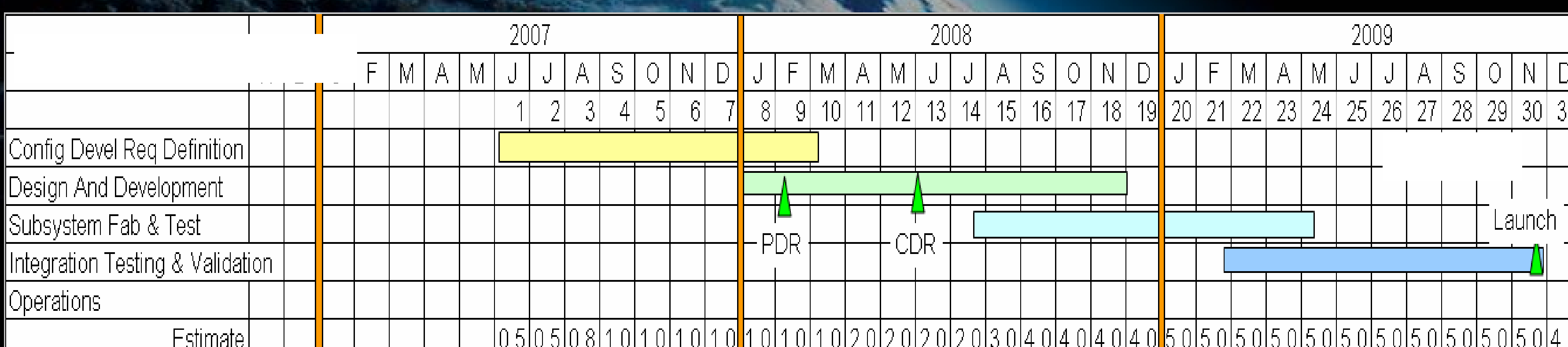
Approach
- Short schedule, incremental development, aggressive Testing
- Heavily leverages DoD investments in propulsion, avionics, and flight software techniques

- Potential missions
  - Equatorial mission – minimal cost
    - Payloads of 1-5 kg with high priority goals
  - Polar mission – maximize launch vehicle capability
    - 40 kg of payload (multiple instruments up to 25 Kg each)

Nominal Cost and Schedule







Areas of Interest

- Tools to enable a geographically distributed, concurrent design of spacecraft systems.
- Database of COTS components and subsystems suitable for small spacecraft, along with methods to keep the database current.
- Modular and scalable subsystem designs for spacecraft.
- Consolidation of spacecraft functions to reduce mass, power, volume and interfaces (i.e., multi-functionality).
- Cross-functional spacecraft-to-payload capabilities in the areas of attitude determination, navigation, telecommunications and other mission level functions.
- Automated test equipment / automated Breakout boxes
- Testing of subsystems in geographically distributed locations
- Standardized interfaces with launch vehicles with frequent launch opportunities

Questions?