AeroAstro

Escort: A Microsatellite for On-Orbit Inspection of Space Assets

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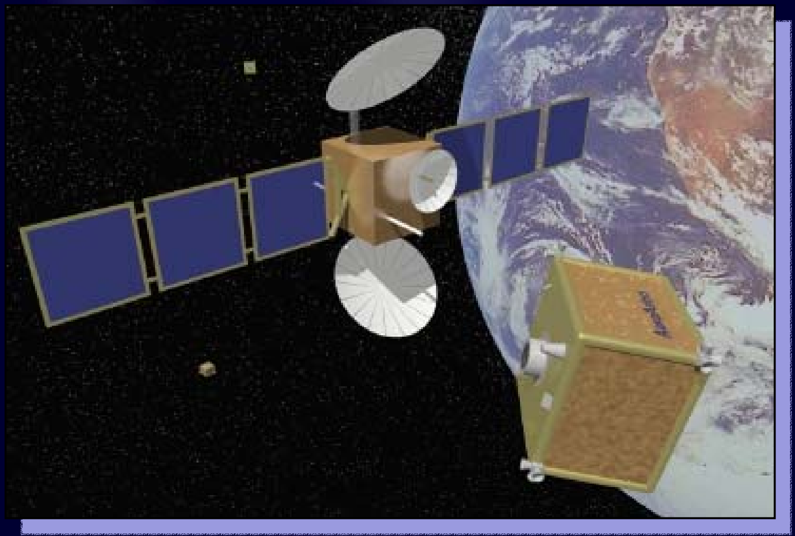
A small Idea

- New Critical Need for **BIG** Satellites:
  - On-Orbit Proximity Inspection by small *"Escort"* Satellites
    - Investigate Anomalies
    - Verify Safety
    - Monitor Performance
    - Aid Deployment and Calibration
  - AeroAstro Says: "small is Useful"
  - Escort Does Not:
    - Rendezvous, Dock
    - Perform Maintenance, Upgrades



Movement

- Escort Does Not Rendezvous Itself
- Escort Still Needs to Get to BIG Satellite
  - Most Commonly in GEO

Option 1

Self-Release from BIG Satellite

Option 2

Use Third Party Services

Large Reusable Orbit Transfer Vehicle

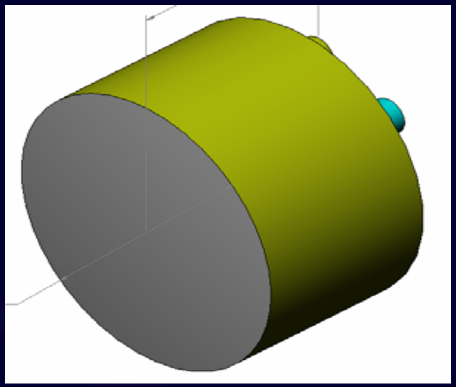
Small Expendable Orbit Transfer Vehicle ~ SHERPA

- OK, it’s There
  - Commence Proximity Operations
  - Escort Orbits the BIG Satellite at Close Range
  - Can Make Small Adjustments to Relative Orbit
  - Could Fly Non Keplerian Trajectories – Depletes Propellant Faster

Escort Inspection Payloads

- RF Probe
  - Analyzes Near Field RF Signals Emanating from BIG Satellite
  - Uses Calibrated Wideband Antenna and RF Front End
  - Back End is Intelligent Spectrum Analyzer with DSP
  - Can Detect and Characterize Signals
- Visual Imager
- IR Imager

  - Radiation Sensor
  - ESD Sensor

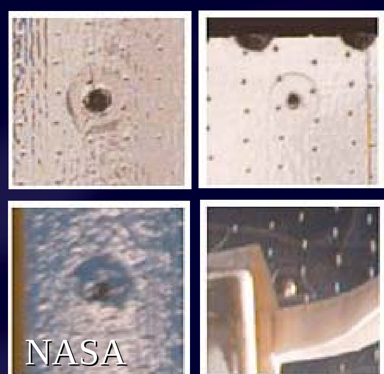


RF Probe

Visual Imager

IR Imager

General Payload Capabilities

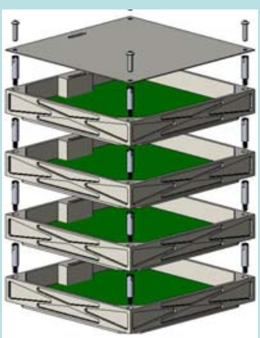
Sensor	Inspections Enabled	Potential Problems Diagnosed	Corrective Actions Possible
IR Camera	• Thermal mapping	• Failed heat pipes • Alpha degradation	• Change heater control plan
Visual Camera	• Macro-scale damage • Micro-scale damage • ADCS anomalies 	• Damaged solar arrays • Failed deployment (solar arrays, antenna reflectors, etc.) • Separation failure • Micrometeorite strikes • Damaged optics • Damaged antenna • Frayed or cut wiring • Erroneous spin rate • Pointing inaccuracies • Propellant leak • ESD arcing • Blanket damage	• Use images to determine whether or not to use thruster assisted deployment or switch to redundant units
RF Probe	• Mapping of antenna gains • Transponder anomalies • Inspection of waveguide assemblies • Inspection of spacecraft processors and clocks	• Antenna gimbal misalignment • Transponder malfunction • Processor stuck in continuous loop	• Re-point antenna • Use Escort as a data relay • Streamlined in-orbit tests (calibration of gimbaled antenna) • Alerts operators to switch to redundant systems

Economic Rationale to Use Escort

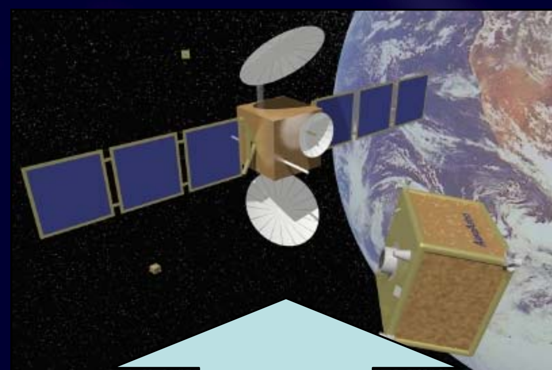
- 100's of BIG GEO Satellites
  - Assume US $400M Each Fixed Cost (inc. Launch)
  - Assume 10 Year Design Life
  - Value of Extending 1 Satellite Life 1 Year = $40M
- Escort Must Extend Lifetime of BIG GEO Sufficiently to Justify Cost
  - Small Satellite Like Escort Easily Costs << $40M
  - Especially In Higher Volume Production
- How To Extend Life?
  - Accelerate Initial Deployment and Calibrations
  - Diagnose Problems Faster – **"IF I COULD ONLY SEE IT!"**
  - Avoid Same Design Problem on Other Satellites On Ground
  - Prevent Same Operations Problem on Other Satellites In Space

Escort Technology Infusion: SBIR/STTR

SCOUT Architecture:
Small, Lightweight
Universal. Compat.
Low Cost
Rapid Response
Flexible
Field Configurable
Modular
Scalable
Extensible

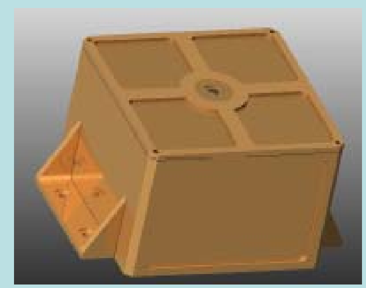


Nitrous Oxide Propulsion



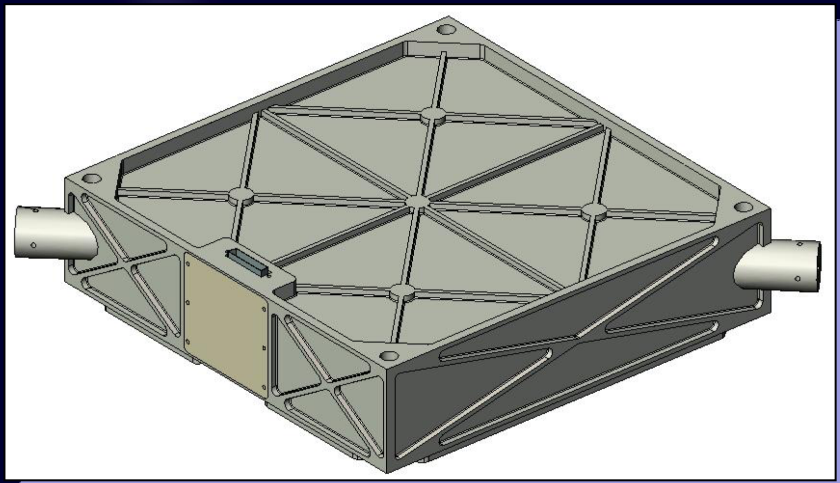
RF Probe

Miniature Star Tracker:



Nitrous Oxide Propulsion

- AeroAstro working with VACCO MEMS and Titanium Technology
- Hot Gas Monopropellant
- Low Pressure (~800 psia) Allows Non-Conventional Tanks
  - Rectangles – Not Spheres
  - More Efficient Use of Volume

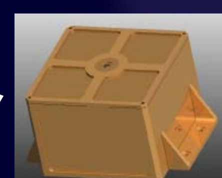


- Non-Toxic, Low-Cost, Storable
- Very Low Freezing Temperature
- 120 < Isp < 200
- Low MIB
- Self-Pressurized by Own Vapor – Liquid and Gas Phases Mix
  - No Diaphragm Needed
  - Special Plenum Ensures Only Gas Gets to Thrusters

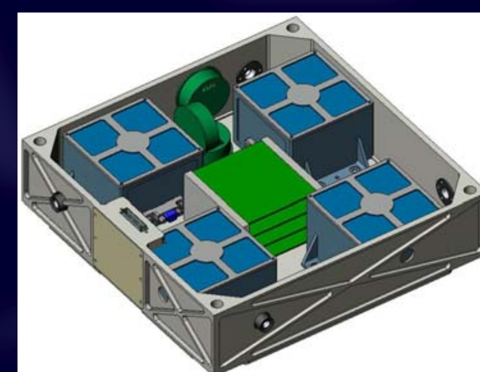
Attitude Sensor Selection

- Robust Design Meets Requirements for Multiple Frames
  - Multiple ST FOV prevents Sun, Moon, Earth induced loss of lock
  - Insensitive to orbit selection
  - Allows for autonomous initial acquisition and Lost in Space mode
  - Sun and rate sensors allow easy autonomous detumble and power-safe modes
- Potential Component Vendors
  - AeroAstro Medium Sun Sensors
  - AeroAstro Miniature Star Trackers
  - Systron Donner BEI Gyrochips (Rate Sensors)

Sensor	Axes/Frame	Quantity
Sun	2/Sun	4
Rate	1/Body	3
Star	3/Inertial	4 FOV, 2 CPU
Imaging	3/Primary	1 (PL Module)



SCOUT Attitude Determination Module



20 × 20 × 6 cm

Attitude Actuator Selection

Figure of Merit	Spin Stabilized	Momentum Bias Wheels	Reaction Wheels	*Selected* Bang-Bang Thrusters
Imager Complexity	High	Low	Low	Low
Pointing Stability	Moderate	Moderate	High	Low
Slew Capability	Low	Moderate	High	High
Power Draw	Low	Moderate	High	Low
Mass	Low	Moderate	High	Low
AD&C Complexity	Low	Moderate	High	Low
Cost	Low	Moderate	High	Low

- Thrusters also very good choice because they can supply needed propulsive maneuvering capability

Attitude Requirements

- Require Ability to Image ~70% of Intended FOV
  - Typical Escort Imager FOV: 5° Full-Angle
  - Require Pointing Control Accuracy: ±1.5°
- Require Unblurred Images
  - Require Attitude Rate Control Accuracy: < ±0.1°/sec
- Require Attitude Determination Accuracy = 1/3 Attitude Control Accuracy
- Selected Components Easily Meet Requirements

Propulsion Sizing

- ~ 100 Days Active Mission Life
- Total Attitude Impulse: ~ 5000 Nms
  - Environmental Disturbances
  - Bang-Bang Limit Cycle (~ 100× more Nms)
- Total Delta-V Budget: ~ 35 m/s
  - Initial Separation
  - Coupled Radial / In-Track Maneuvering (100 m per day)
  - Cross-Track Maneuvering (100 m per day)
  - North-South Station-Keeping
  - East-West Station-Keeping
  - Orbit Translation Bang-Bang Limit Cycle
  - Disposal to Super-GEO
  - Attitude Control Compensation for Thruster Offset Disturbance During Translational Maneuvers

~40 kg Dry Mass

~5 kg Propellant Mass

Relative Orbit Dynamics Overview

- Escort Passively Orbits BIG Sat Most of Time
- Could Lead or Trail Also
- Relative In-Track and Radial Motion are Coupled
  - In-Track = 2 × Radial
  - Can Manipulate in Terms of Apogee and Perigee
- Relative Cross-Track Motion is Independent
  - Can Manipulate in Terms of Inclination
- Smaller Radius of Relative Orbit → Slower Motion Relative to Primary
  - Safer
  - Longer Dwell Time on Small Features
- 100 m < Radius < 1500 m
- Imager can Meet Requirements Well Within Close and Far Distances:
  - 1 cm Resolution at 100 m
  - 50 m Projected Field of View at 1500 m

Operations Concept

- Payload Data Downlink from GEO Very Power Consuming
  - Suspend Operations Temporarily
- Leads to “Campaign” Operations Concept
- ~ 3 to 4 Campaigns Per Day
  - Maneuver
  - Collect Payload Data
  - Downlink and Recharge
- Each Shift of Operators Conducts Single Campaign
- Long Term Hibernation Also Possible
  - Avionics Reliably Radiation Tolerant for ~ 1 Year