

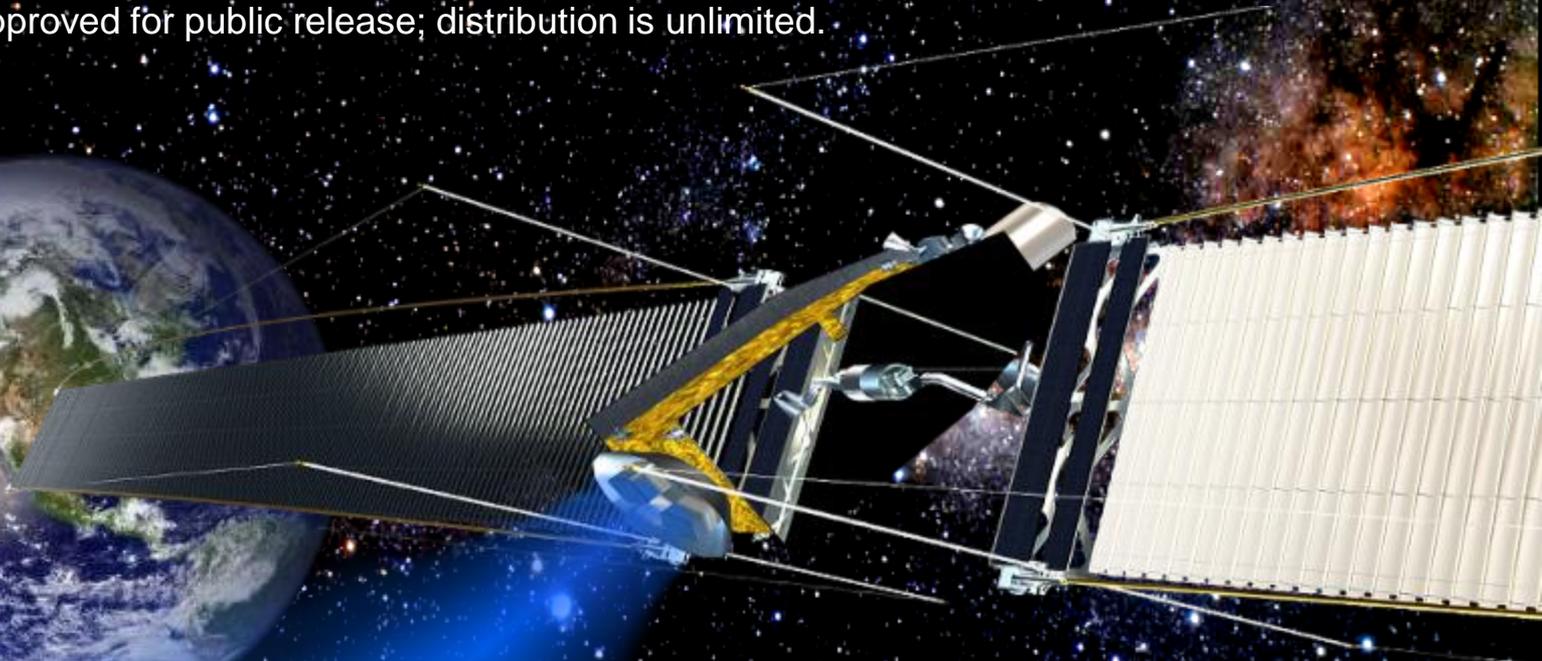


FAST Nimitz –

A Powerful, Highly Mobile Platform to Address Space Debris in Any Orbit

DISTRIBUTION STATEMENT A

Approved for public release; distribution is unlimited.



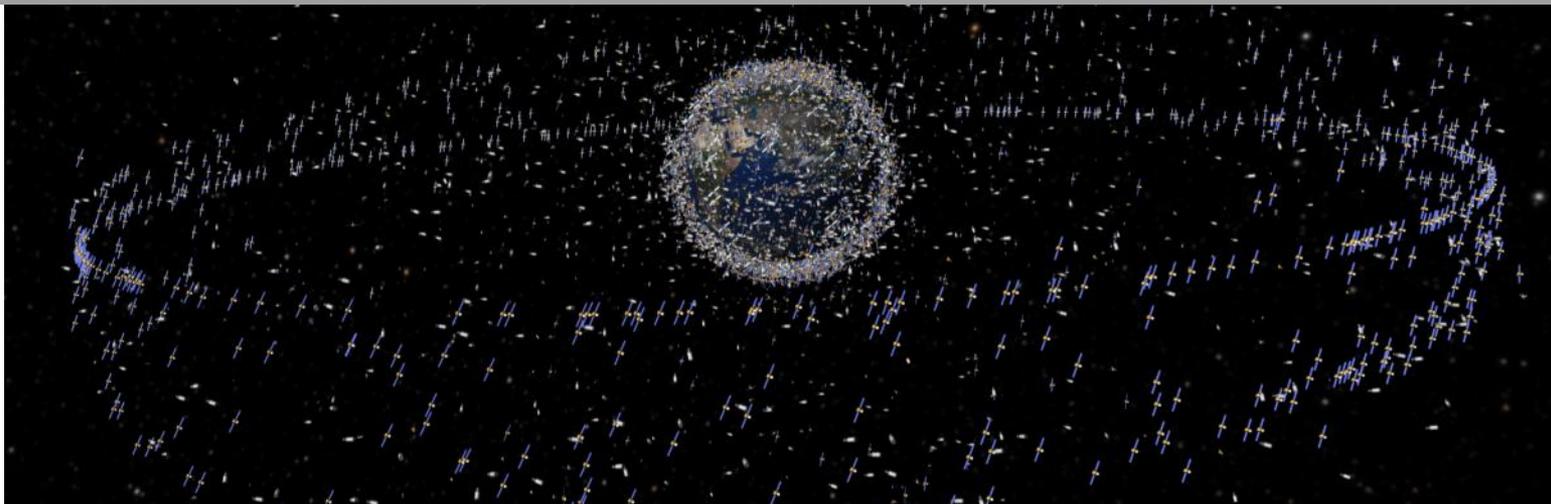
Tom Kessler
Boeing Advanced Systems
(714) 658-4733
Thomas.L.Kessler@boeing.com





Space Debris Is An Increasing Threat to Both GEO and LEO Operations

Integrated Defense Systems | Phantom Works 



- About 40% of ground-trackable space debris come from explosions, now running at four to five per year.
- Collisions will exceed explosions as a source of new debris within 20 years
- Collisions between live spacecraft and other objects can be mitigated by better tracking

First priorities should be to reduce threats of

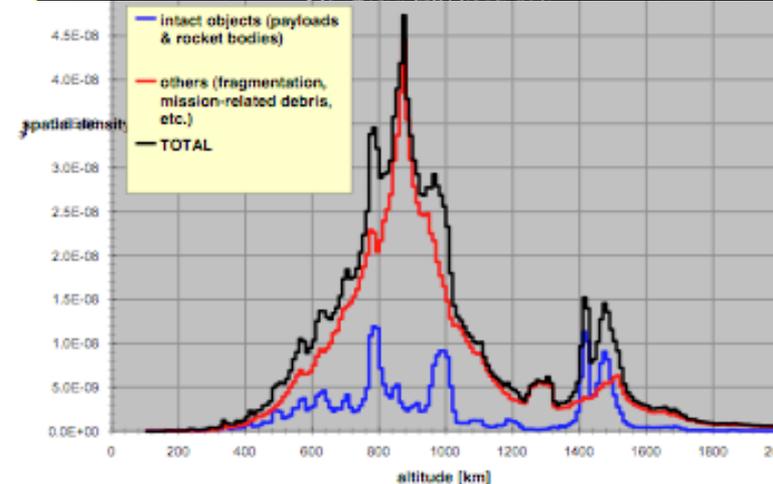
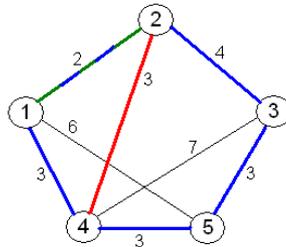
- *Upper stage / spacecraft explosions*
- *'Dead-on-dead' debris collisions*



Space Debris is In Many Inclinations And Altitudes

Integrated Defense Systems | Phantom Works 

- LEO debris is scattered in inclination, Right Ascension, and altitude
- Cost effective, timely solution requires that multiple debris objects be engaged per mission/vehicle
- “Traveling Salesman Problem”
 - For a given list of cities (*debris targets*) and their pairwise distances (*delta-V*), what is the shortest possible (*least energy*) tour that visits each city once.



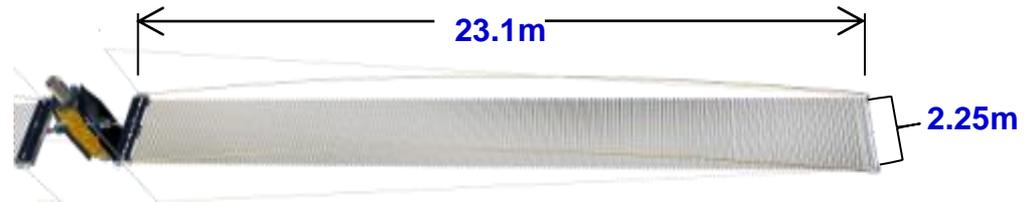
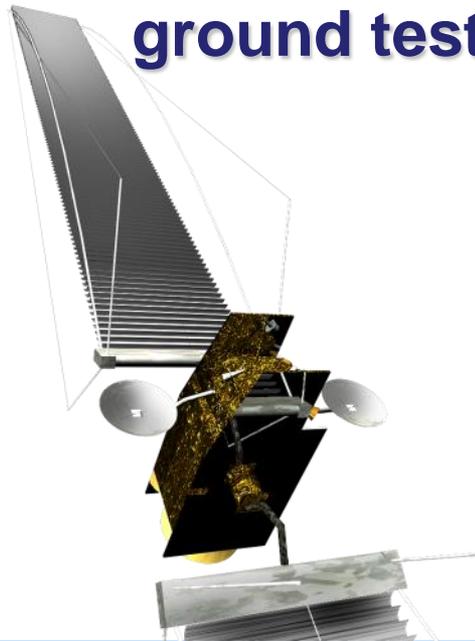
Effective space-based solution should have high delta-V



FAST Program Overview

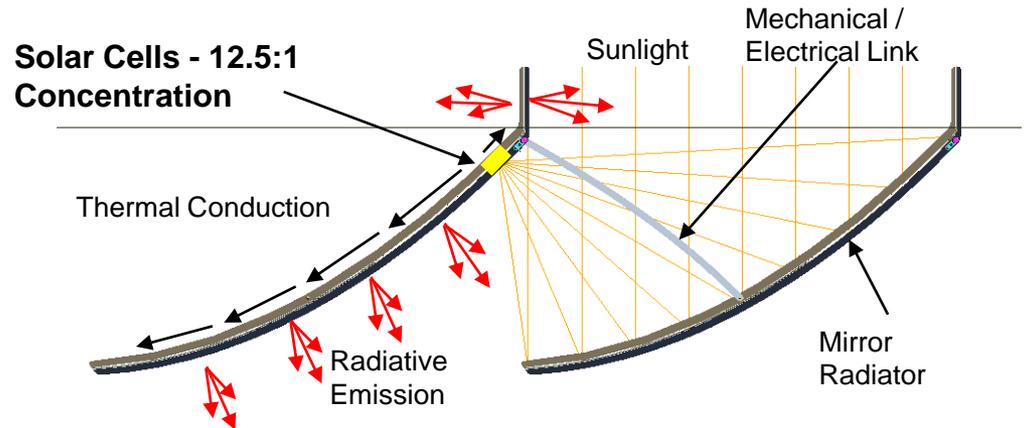
Integrated Defense Systems | Phantom Works 

Fabricate a high power and light weight solar electric array that can support a wide range of space applications, and ground test it in a relevant space environment



Basic FAST 15 KW Solar Wing Building Block

GOALS
~30 kWe electrical power
>130 W/kg specific power
Scalable to 100 - 1,000 kWe



MCA Solar Performance Characteristics



Key FAST Features

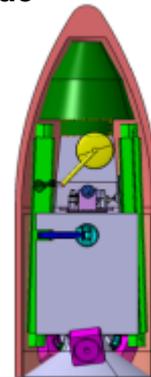
Integrated Defense Systems | Phantom Works

Inherent scalability

- Design is modular, one array (2 wings) yields ~30 kWe
 - Modular approach scales up, dimensions by 2X, area by 4X
 - **Modular:** Up to six wings can be flown in tandem for 180 kWe
 - **Scalable:** Doubling wing dimensions yields ~720 kWe
 - Future technology will scale up power & reduces mass
 - Scaling up dimensions
 - Advanced solar cells
- } Potential for > 50% increase in specific power in next decade

Flexible launch vehicle packaging & interface

- 4X better packaging efficiency than state of the art
- SLV → 30 kWe HPGS, packages in
 - 1.7m Falcon 1E fairing
 - Minotaur IV
- EELV → Scaled-up 180 kWe system fits in 5m fairing

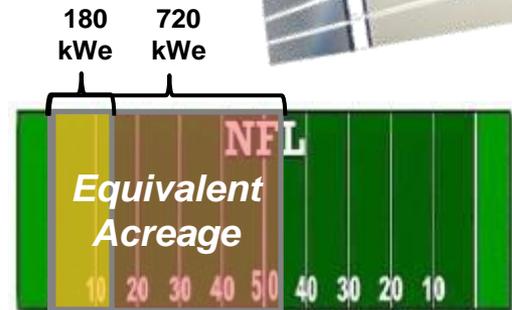


30 kWe Array in Falcon 1E

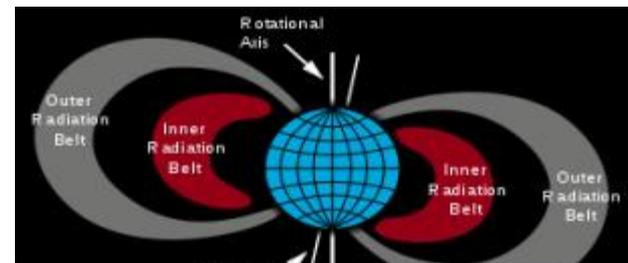
Inherently survivable/hardened configuration

- Laser survivability due to MCA geometry
- More radiation tolerant due to shielding of surrounding MCA structure
 - Supports multiple passes through Van Allen Radiation Belt

180 kWe or 720 kWe Concept



Big when scaled up...but not too big



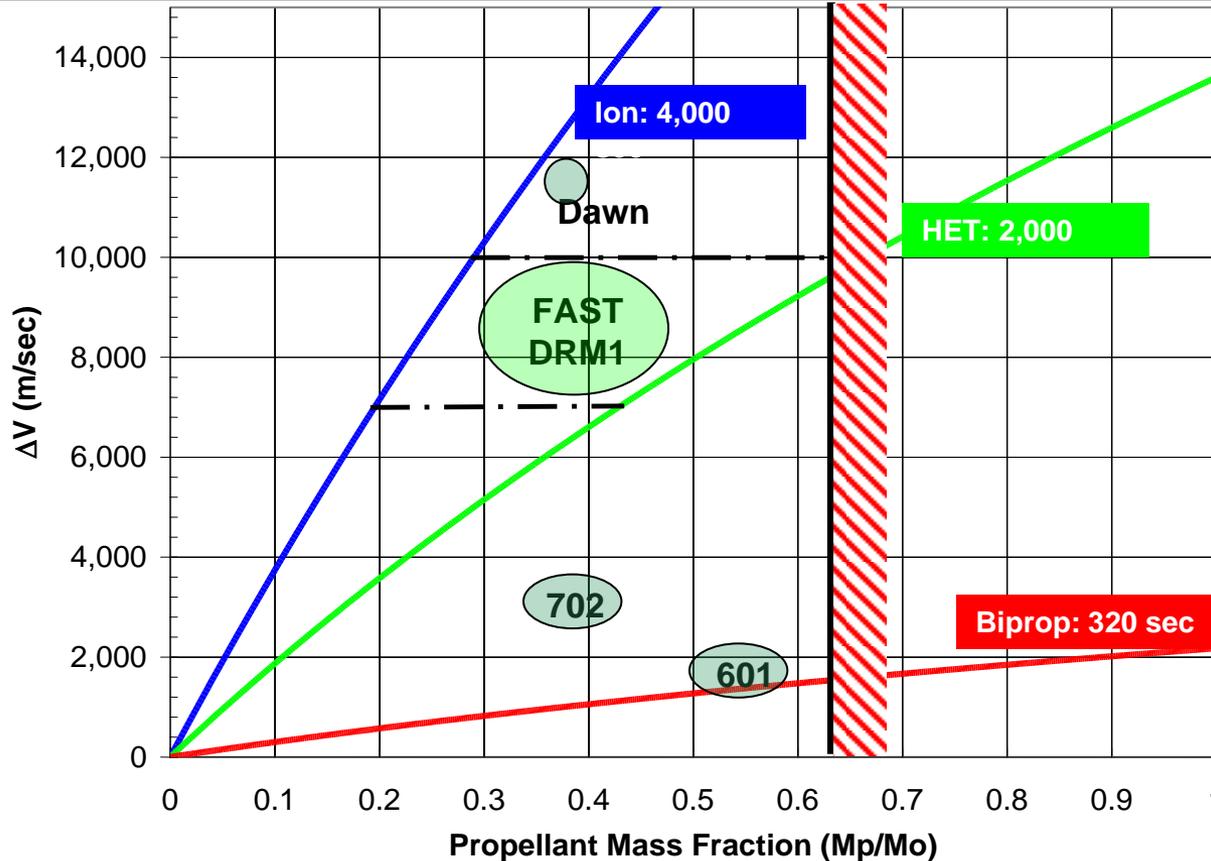
Enables LEO to GEO round trips (RT)

| RT time (days) | Number of RT |
|----------------|--------------|
| 60 | 13 to 17 |
| 100 | 9 to 11 |
| 125 | 6 to 7 |
| 200 | 4 to 5 |



FAST Enables Very High Power Electric Propulsion and an Order-of-Magnitude Greater Delta-V

Integrated Defense Systems | Phantom Works 



FAST spacecraft configurations with useful payloads offer 9,000 – 14,000 meters/second of delta-V

Boeing Has Demonstrated Fully Autonomous Rendezvous (with or without client aids)



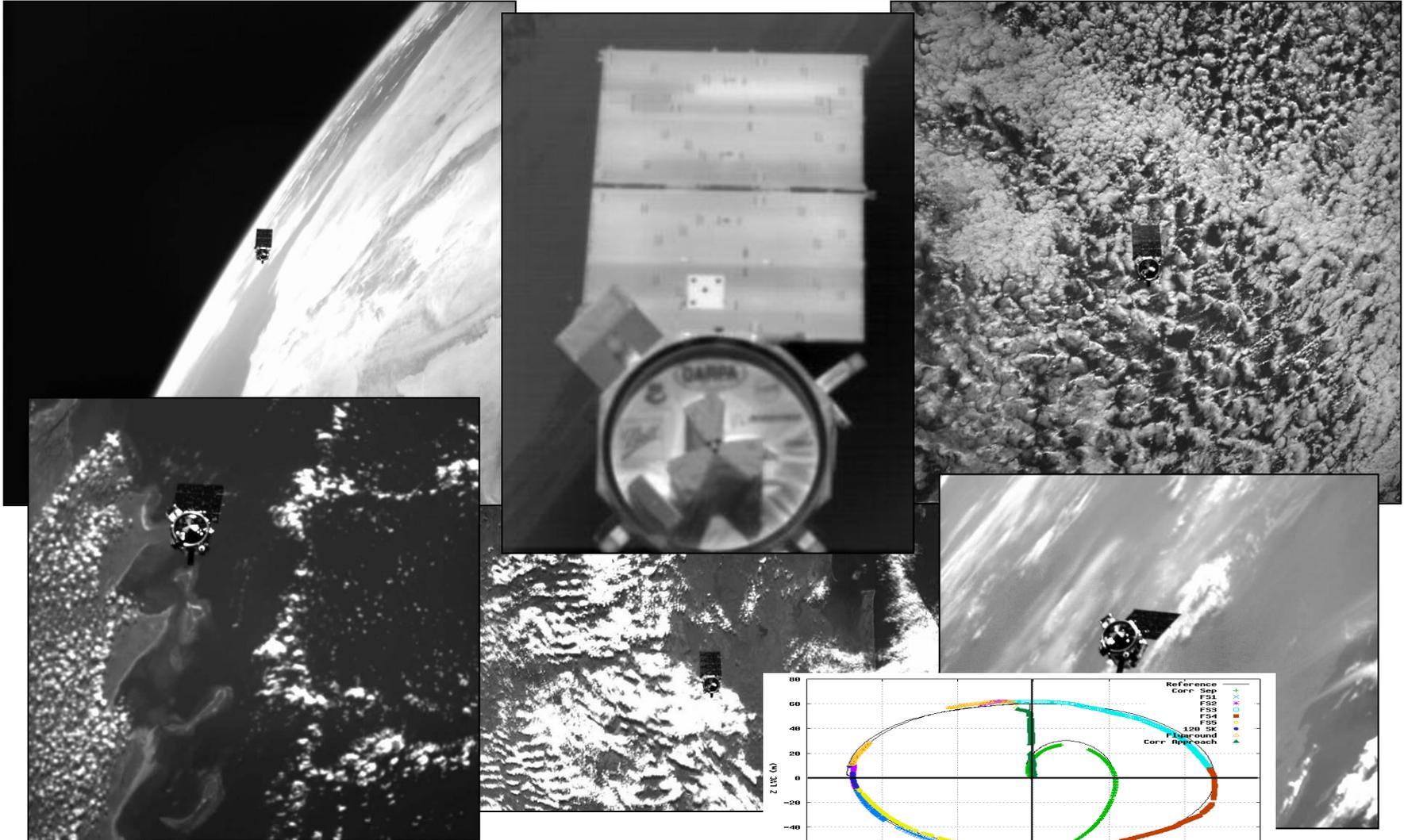
DARPA ORBITAL EXPRESS MISSION 16 JUNE 2007 – 3RD RENDEZVOUS SCENARIO

BOEING ASTRO SPACECRAFT IMAGES THE NEXTSAT
DURING DEMONSTRATION OF RENDEZVOUS & PROXIMITY OPERATIONS



Orbital Express Demonstrated Fully Autonomous RPO from 200 KM in to 10 CM

Integrated Defense Systems | Phantom Works 



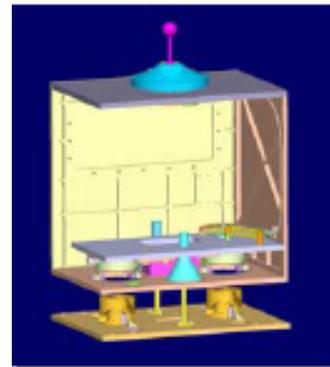
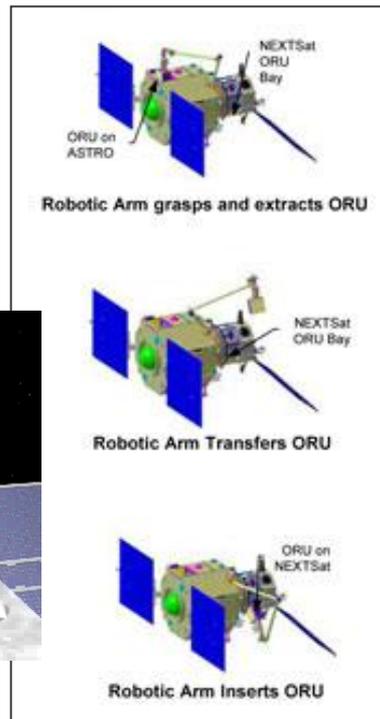
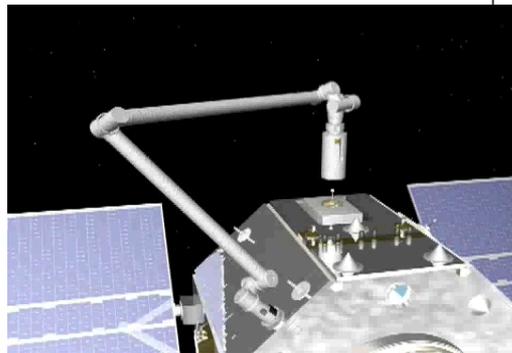


Orbital Express Demonstrated Fully Autonomous ORU and Propellant Transfer

Integrated Defense Systems | Phantom Works 

- Northrop Grumman-provided hardware demonstrated autonomous transfer of hydrazine propellant to and from the NextSat spacecraft 15 times
 - Multiple types of fuel transfers are demonstrated
- MDA-provided robotic arm demonstrated eight battery and computer transfers in both directions between the Ball and Boeing spacecraft for both a battery and a flight computer module

Nimitz itself can be refueled – further extending it's capability and improving overall economics



ORU



Summary

Integrated Defense Systems | Phantom Works 

• FAST Nimitz offers revolutionary capability for debris mission

- High Performance – Vast improvement over Bi-Prop propulsion and SOA solar arrays

| Metric | Bi-Prop | FAST with EP | Advantage |
|-----------------|----------|--------------|------------|
| Total S/C Power | 1 kW | 30 KW | 30x more |
| Delta-V | 1-2 Km/s | 9-14 Km/s | 5-10x more |

- Cost effective - This delta-V can allow removal/supersynching of many large GEO or LEO debris objects in a single mission

▪ Boeing's FAST team has or is demonstrating the key Nimitz technologies

- 30 KW High Power Generation System Module
- 24 - 30 KW electric propulsion system
- Fully autonomous Rendezvous & Proximity Operations GN&C systems for space debris
- Highly flexible robotic systems developed under FRENDS & Orbital Express programs

▪ FAST Nimitz can carry multiple payloads to affect space debris of many types in many useful ways:

- Direct capture/transfer/de-orbit of large debris
- Indirect, non co-orbital deployment of de-orbit systems
- Etc.



Conclusion

Integrated Defense Systems | Phantom Works 

- **As the leading manufacturer of satellites in the world, Boeing is committed to supporting our customers critical mission operations in space, including effective responses to the space debris issue**
- **Nimitz could deliver, power or otherwise work in concert with many debris mitigation payloads**
- **We are very interested in collaborating with the developers of these systems**
- **Please contact me at**
 - Tom Kessler
 - Boeing Advanced Systems
 - (714) 658-4733
 - Thomas.L.Kessler@boeing.com

