DARPA's Phoenix Project

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GSFC

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Who is DARPA?

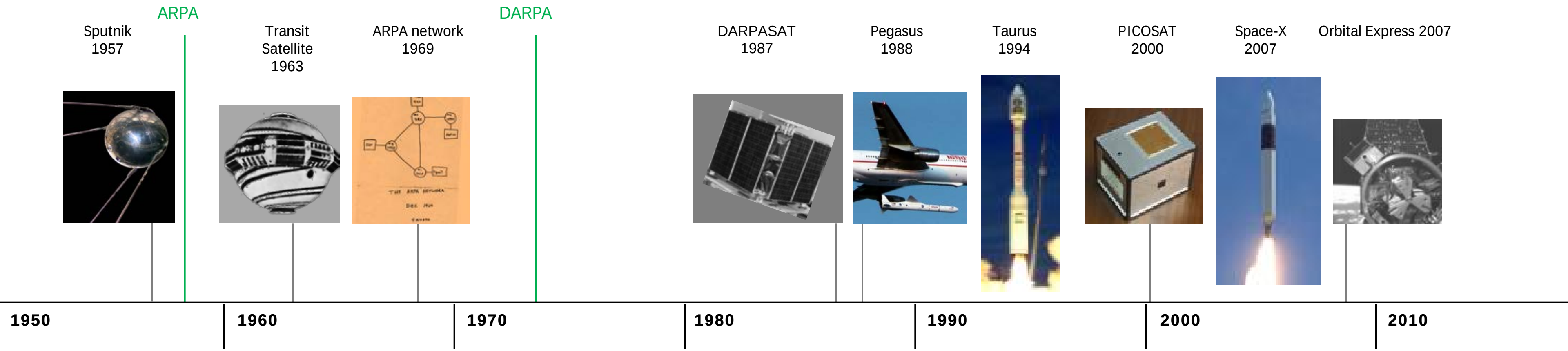
In 1958, Advanced Research Projects Agency
was created to pursue high-risk, high pay-off advanced technology.

In 1972, ARPA was renamed the
Defense Advanced Research Projects Agency.

DARPA breaks the gridlock of military competition for resources and recognition that hindered early U.S. space technology development.

DARPA's progressive, risk-tolerant leadership fostered:

- Cooperation among government agencies.
- Healthy competition in the marketplace.



Organization

AEO
Adaptive Execution Office

- Agile Programs with Frequent Development Cycles
- Conduct Systematic Rigorous
- Assessments
- Explore New Contracting Approaches
- Develop Strong Relationships

DSO
Defense Sciences Office

- Physical Sciences
- Materials
- Mathematics
- Training & Human Effectiveness
- Biological Warfare Defense
- Biology

I2O
Information Innovation Office

- Global ISR
- Cyber
- Social Networks
- Computational Social Science
- Language Transparency
- Edge Finding
- Training/ Education

MTO
Microsystems Technology Office

- Basic Science Core
- Devices
- Integration
- Power
- Architectures
- Application

STO
Strategic Technology Office

- Comms & Networks
- Global Tactical ISR
- Energy
- Hybrid Warfare
- Extreme Environments

TTO
Tactical Technology Office

- Advanced Weapon Systems
- Advanced Platforms
- Advanced Space Systems

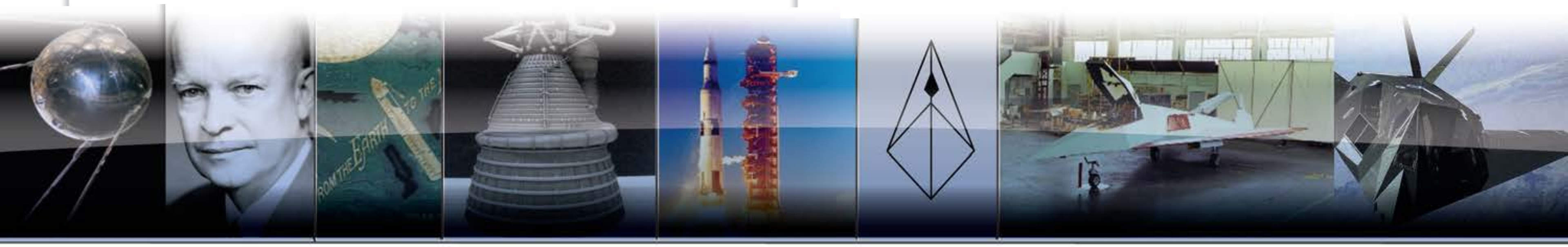
DARPA/TTO is always looking for new PM candidates

Characteristics of a Successful TTO Program

- Singular mission to prevent and create strategic surprise
- Focus on innovation of revolutionary technologies to support the warfighter
- High-risk/high-payoff investments beyond horizons of service lab efforts
- Programs with finite duration culminating in an advancement of knowledge or a measurable capability demonstration

Characteristics of a Successful TTO Program Manager

- **World-renowned expert** in one or more TTO focus areas
- **Passionate visionary** for the development of revolutionary technologies to support the warfighter
- **Talented manager** of people and conscientious steward of taxpayer dollars
- **Adept communicator** of program impact



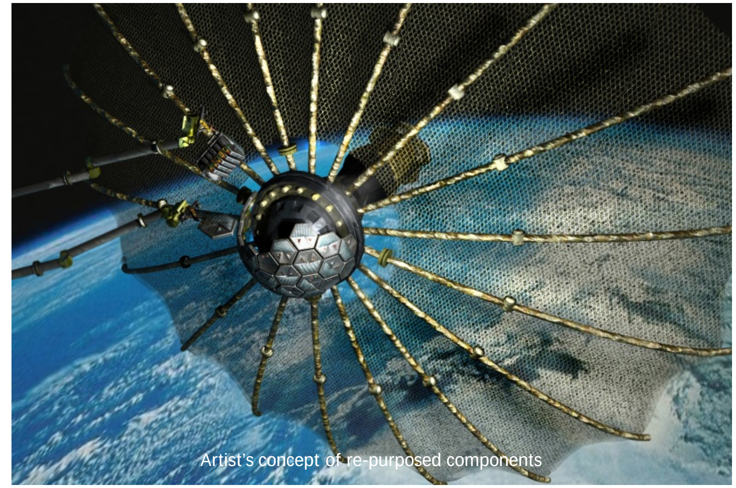
TTO Focus Areas

Space Systems & Space Awareness	Aero- & Hydrodynamic Systems	Manufacturing of Weapons & Platforms
Hypersonics	Ground & Soldier Systems	Qualification / V&V
Space Access	Design Synthesis	Autonomy

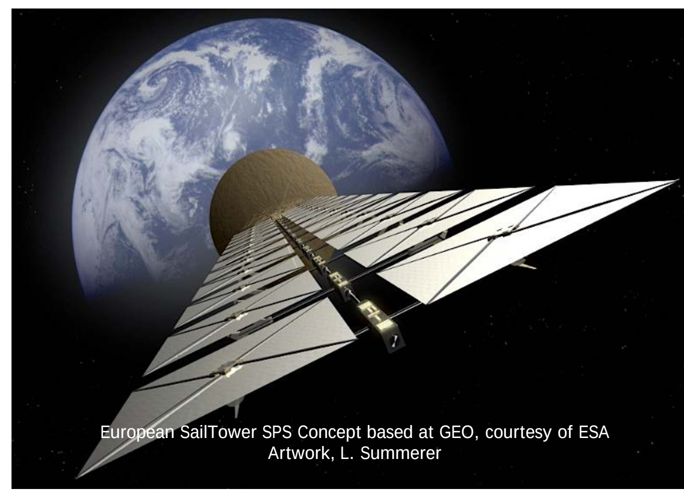
From an initial idea to ....

...the Phoenix vision

- Change how satellites are built, shifting to on-orbit assembly.
- Ability to upgrade satellites faster to accommodate new electronics/technologies.
- Able to increase effective DoD/US Government Return on Investment by re-using highest value components on orbit.
- Allow non-traditional space suppliers and players to enter space market using high volume low cost manufacturing through dispensed COTS hosted payload delivery.
- Enabling true "assembly in space" to physically build very large apertures for both RF and optical systems.



Artist's concept of re-purposed components



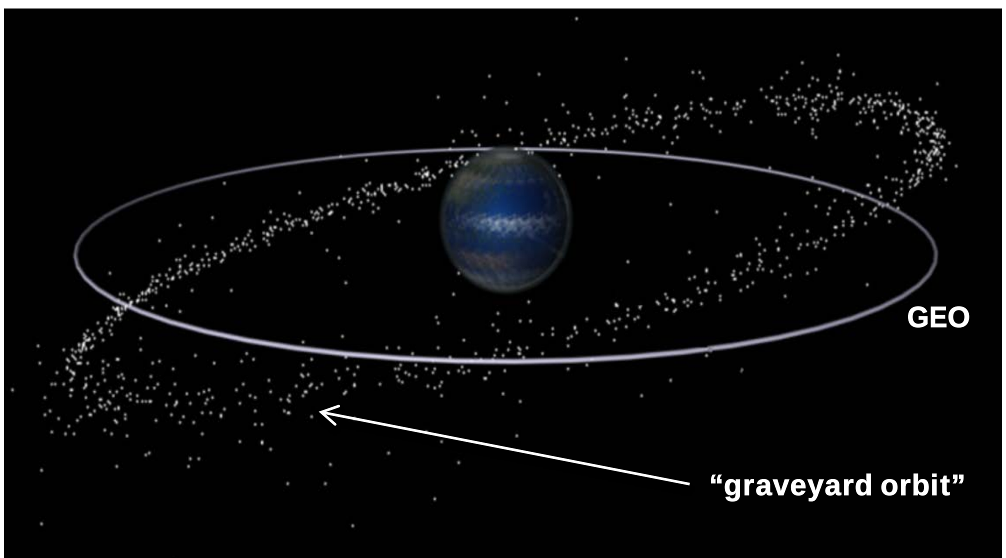
European SailTower SPS Concept based at GEO, courtesy of ESA
Artwork, L. Summerer

The precept of return on value through simple re-use is used everywhere on earth, except in space...

Aircraft (ie US Air Force B52’s) are upgraded multiple times over their life...

Ships are re-furbished multiple times over their life....

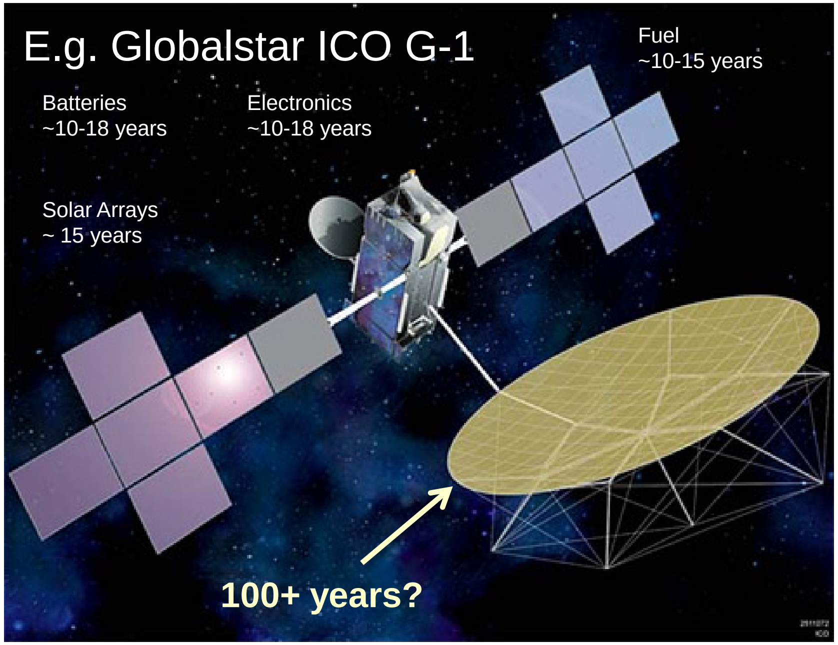
Ground vehicles are re-furbished multiple times over their life....



Over 1300 satellites since the 1960’s with estimated value over $300B are “thrown” away in Geostationary orbit…

Is it possible to “re-use” satellites?

GEO-based "retired " apertures have already incurred the highest costs in a space system mission life cycle: **fabrication, launch & deployment**.

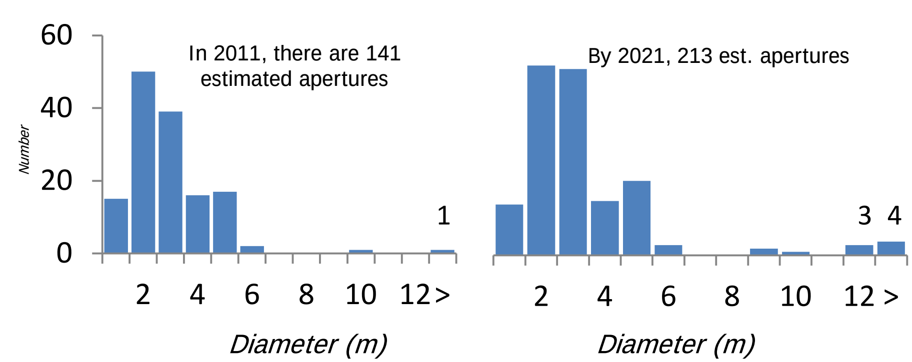


Apertures in GEO have

- **Stationary persistence**
- **Large field of regard**
- **Lifetime**

Larger apertures provide flexibility in throughput (ie bps), # of users, or lower power on the ground to close a given frequency.

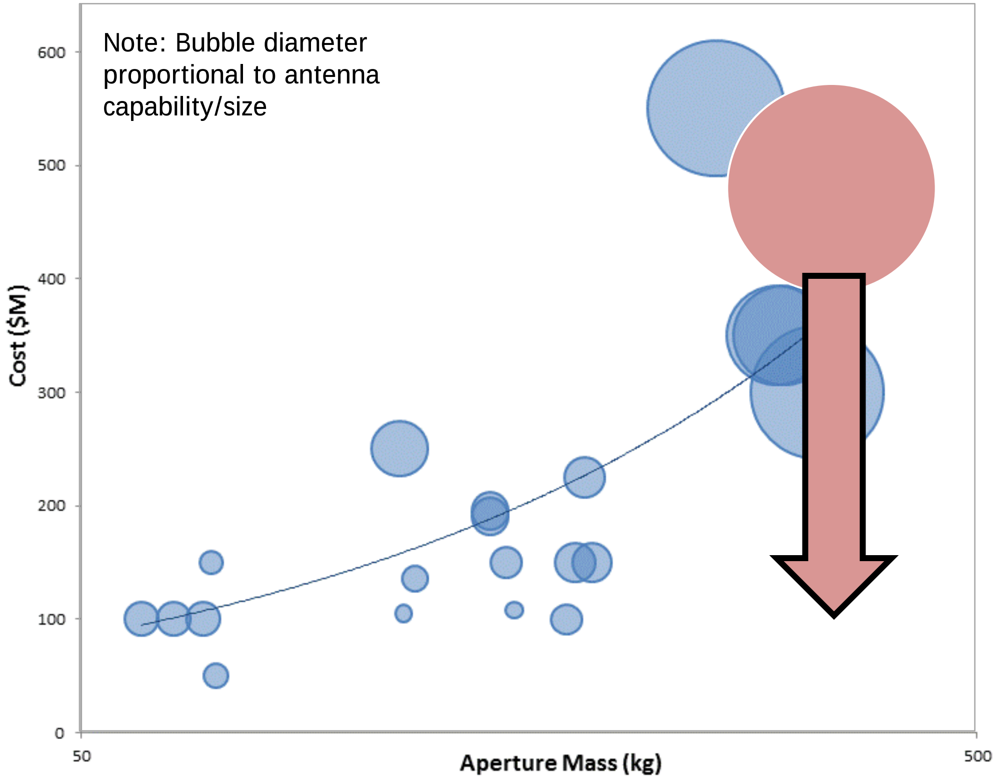
Selected decommissioned GEO assets identified from GSFC database



Phoenix proposes to "re-purpose" existing apertures in GEO as a first demonstration of recycling on-orbit assets that could support DoD missions.

To be viable, the cost to “grab and add” supporting mass to existing apertures must be substantially below replacement costs, achieved at a much higher tempo

Traditional satellite architecture and tempo have spawned a simple cost calculus based on mass



Based on survey of commercial communications satellites cost versus 1% of Satellite Mass (to estimate aperture mass)

Relevant observations:

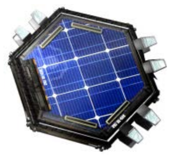
Most cost efficiency is typically through higher number of units sold/delivered per unit time…

… existing commercial “service’s” typically offer excess mass to space (i.e. GEO) on a monthly tempo

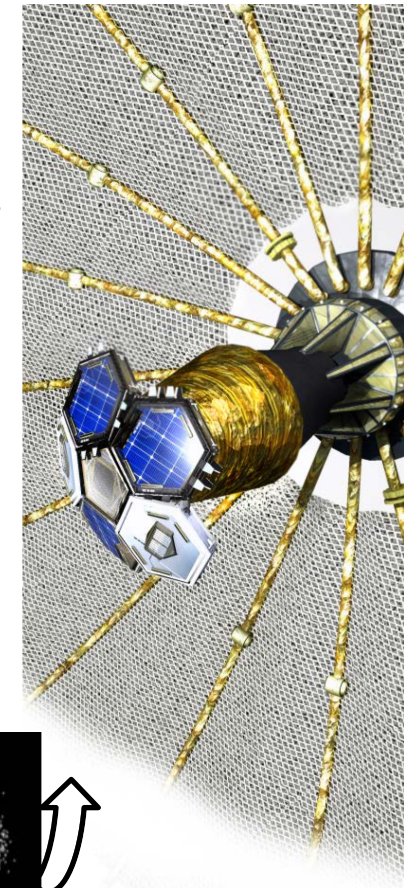
It is possible to change the cost vs mass ratio at the same performance point for space systems by combining high volume low cost manufacturing production with re-use of existing apertures…

Phoenix translates the initial vision into three basic concepts

New definition of “Spacecraft”

Repurposing retired components into value added systems or services

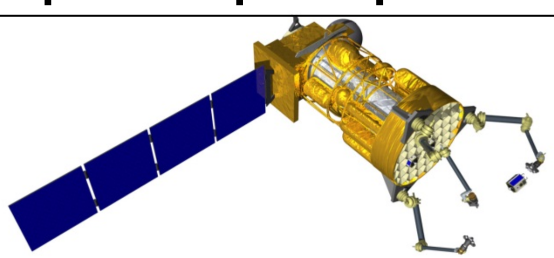


Increasing tempo of mass to orbit

Eg. SES-2, host to CHIRP

Eg. Intelsat 14, host to the IP Router In Space (IRIS) Joint Capability Technology Demonstration

Standards for on-orbit space to space operations



How to change satellite definition?

Look at how nature "builds" complexity

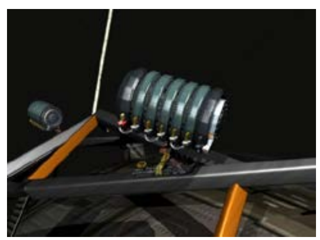
Prototypes: 2013

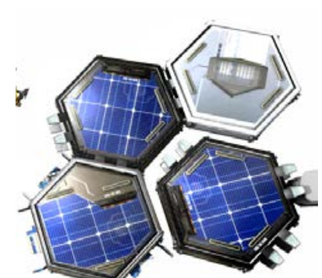
Biology aggregates specialty cells for performance at various scales.		
	# of Specialty Cell Types	Typical Cell Total
Placozoa	4	Few thousand
Hydra	15	50-70,000
Jellyfish	22	Several Million
Satellite	~8*	~8-25*

*Satellite subsystems that could be "cellularized", e.g.
Power subsystem
Attitude control, secondary structure
Attitude determination
Telemetry, tracking and control
Command and data handling
Thermal subsystem
Primary structure
Propulsion

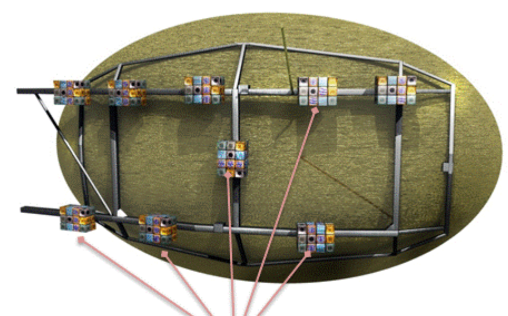
"Satlet's"

- Changing satellite morphology by developing individual "cell's" to provide specific function(s), either singularly or aggregated.

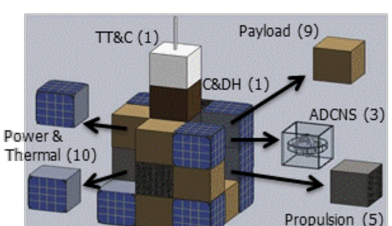


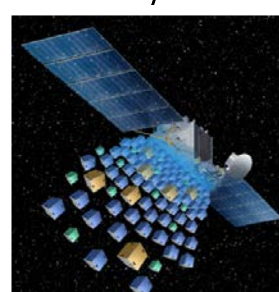


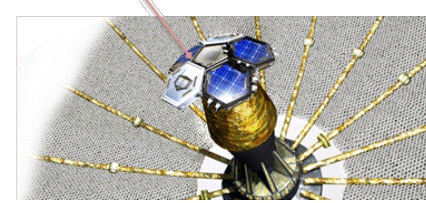
Artist's Concepts



Example of n-Satlets placed on antenna structure and at RF collector feed.



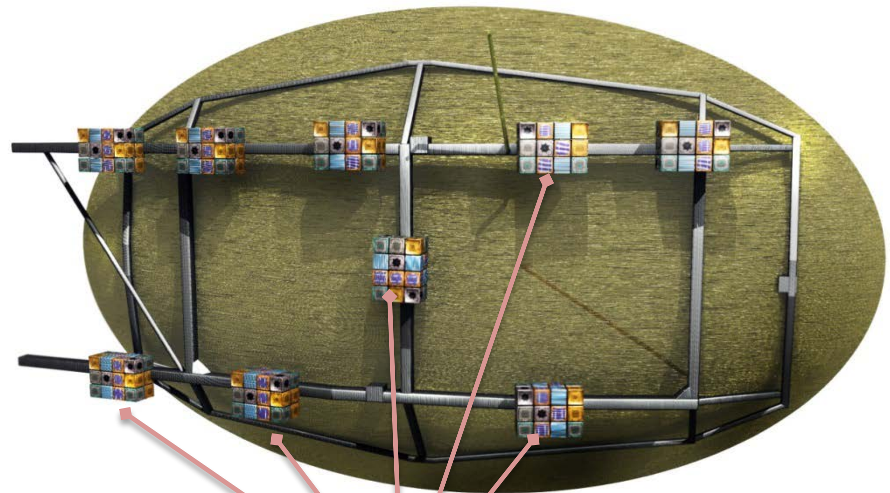




Example of Satlet "aggregation" for Phoenix

Example aggregation of Satlets for repurposed antenna:

- Maintain attitude control of 100kg kg aperture using N Satlets, each with TBD Nm-s momentum control, aggregated together
  - Control to +/- 10 degrees pointing at Earth
- Provide RF collection point
- Provide means to control momentum buildup



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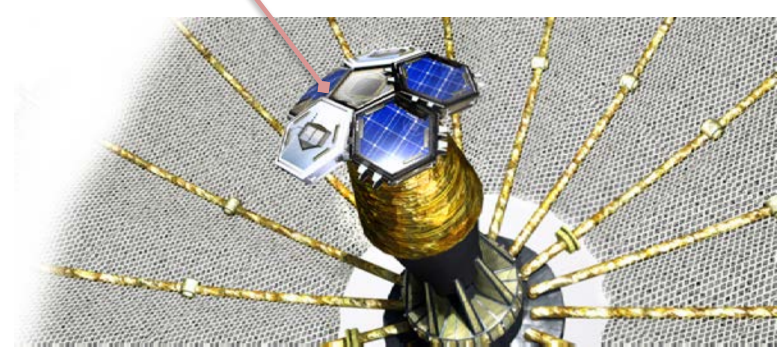
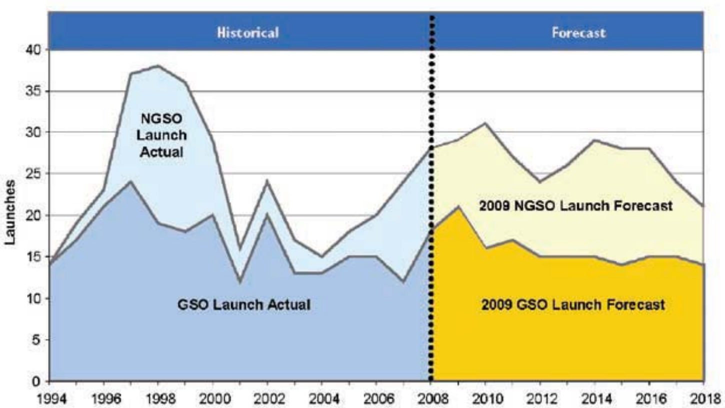


Derived Requirements (eg):

- Cross-Satlet communications to coordinate aggregated control
- Ability to accept external communications as to the vector by which the Satlets collectively must point to.
- Appropriate processing to coordinate attitude control and cross Satlet communications
- Power to support the aggregated Satlet functions
- Ability to grasp/grapple antenna, and aggregate with each other

How to enable cheaper access to space?
Increase tempo of mass to orbit…

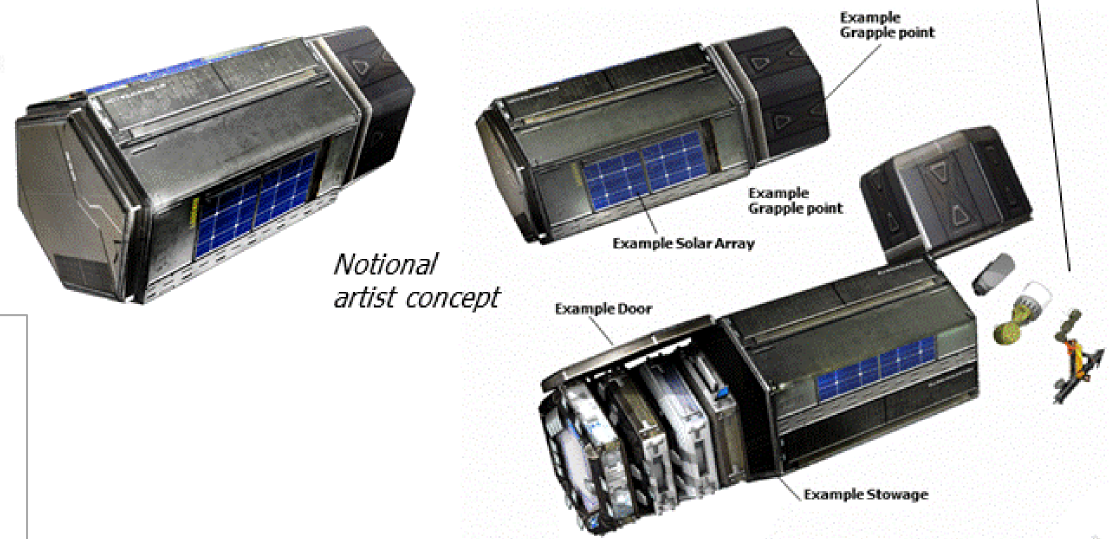
Demo: 2015



[FAA Aerospace *Forecast* FY 2010-2030.indd]

PODs are meant to contain multiple Satlets, tools, electronic boxes of varying sizes and shapes launched on any comm satellite

Multiple tools for Servicer/Tender stored in the PODs.



Notional artist concept

PODs (Payload Orbital Delivery System)

- Structural container that supports Satlets, tools, electronics, etc. during launch on a hose communications satellite.
- Can be dispensed into space to be picked by the Servicer/Tender.

Combining "volume" production with increased delivery to GEO creates a pipeline to support component repurposing

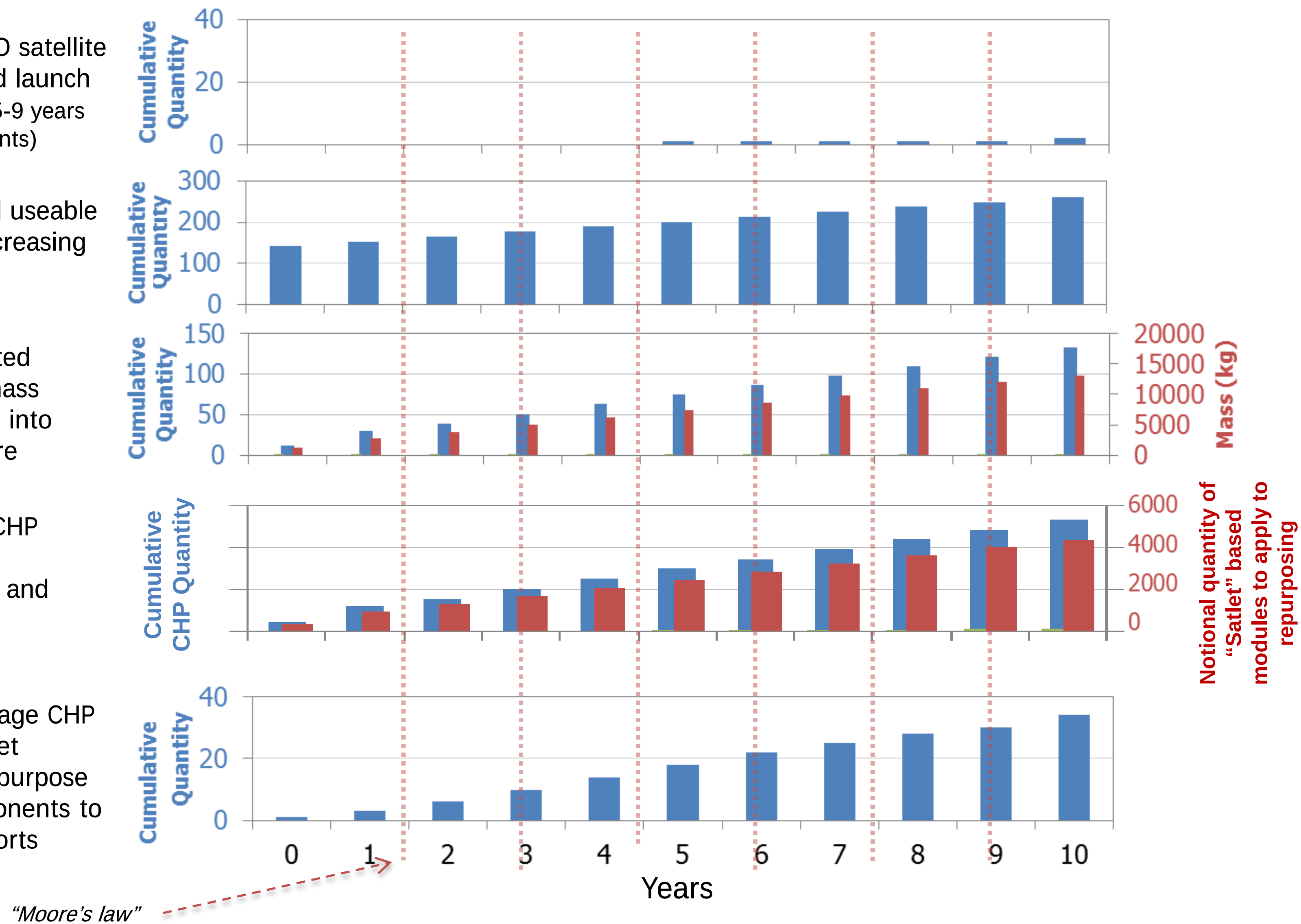
Current DoD GEO satellite development and launch tempo (between 5-9 years between deployments)

Decommissioned useable apertures are increasing each year

Commercial Hosted Payload (CHP) mass is ~1000kg/year, into foreseeable future

Possible to use CHP opportunities to increase volume and tempo of Satlet aggregation

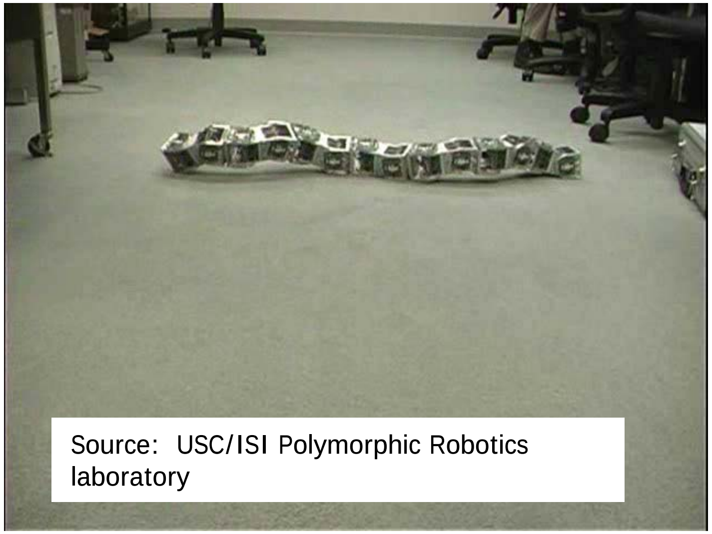
Possible to leverage CHP and volume Satlet production to repurpose apertures/components to support DoD efforts



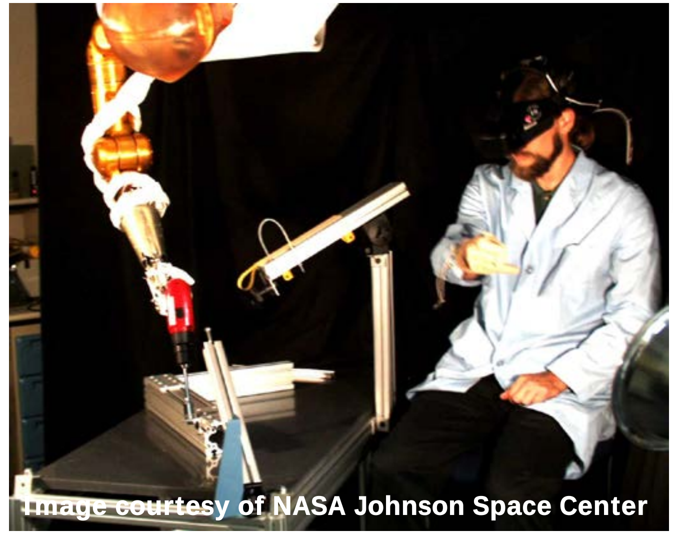
How to execute safe and ubiquitous “servicing” in space?

Explore model standards for space to space operations…

Multi-dexterous robots

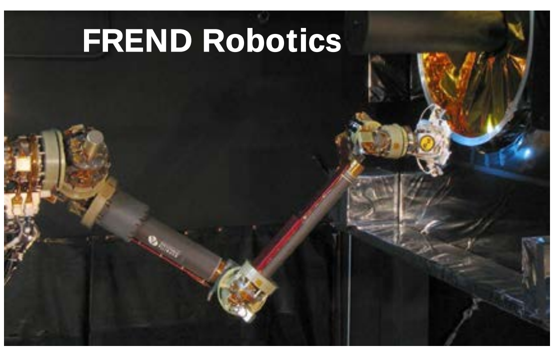


Human Tele-presence systems

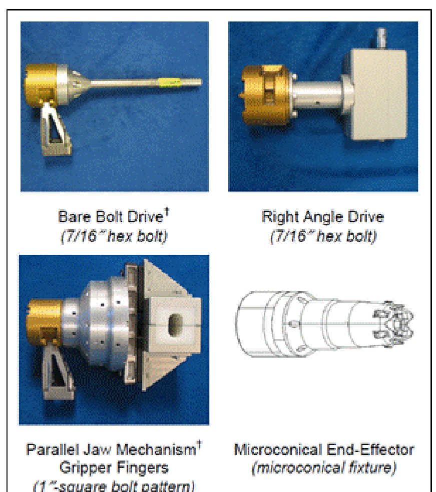


Phoenix Flight: 2015/16

Primary Robotic Arm

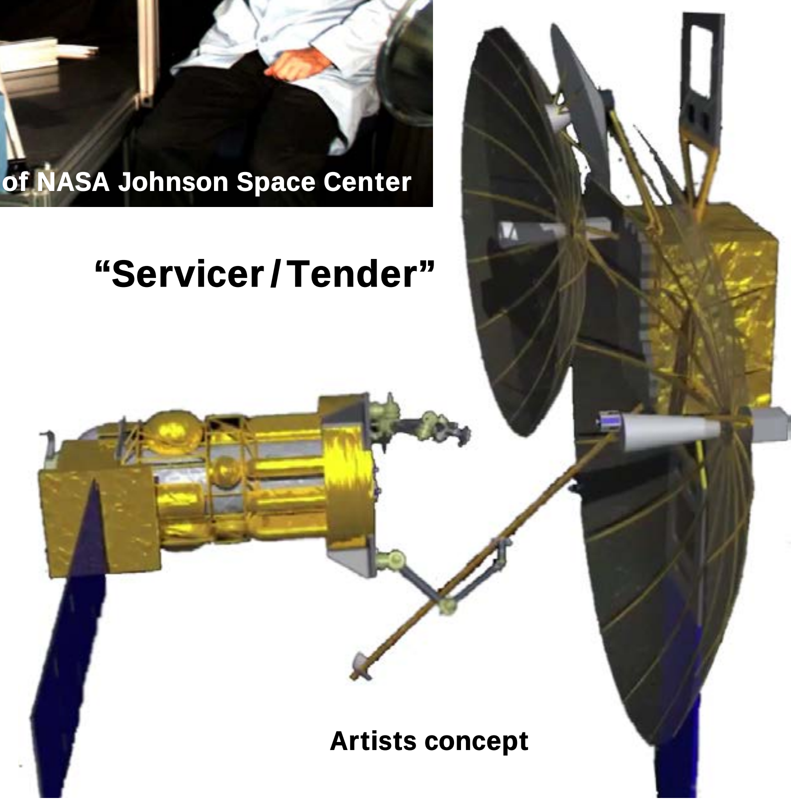


Simple & complex toolsets



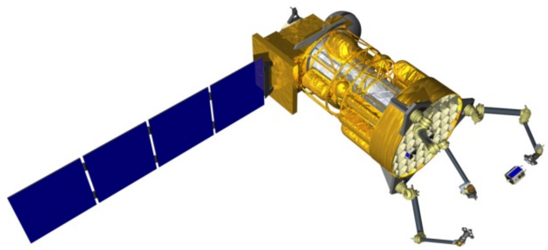
Source: University of Maryland, Space Systems Laboratory

“Servicer / Tender”



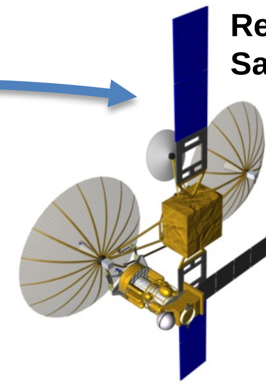
Artists concept

Phoenix architecture encompasses a host of technical elements that contribute to the concept of operations

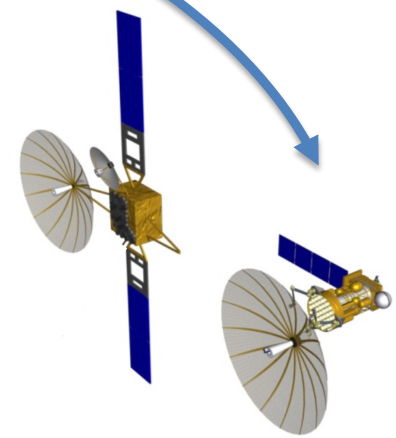


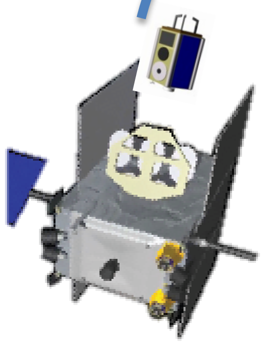
Tender / Servicer Spacecraft

- Spacecraft Bus.
- RPO Sensors.
- Primary Robotics (FREND Arms).
- Tools/end effectors and Tool Changers.
- Next generation hyper-dexterous manipulator
- Toolbelt and/or Toolcaddy.
- High performance Ground-Servicer/Tender Comms.
- Tele-presence algorithms and S/W.



Retired Communications Satellite





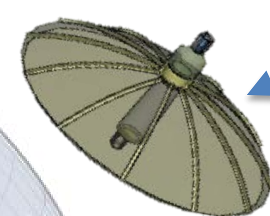
Commercial Communications Satellite to host Ridealong PODs

New Technologies

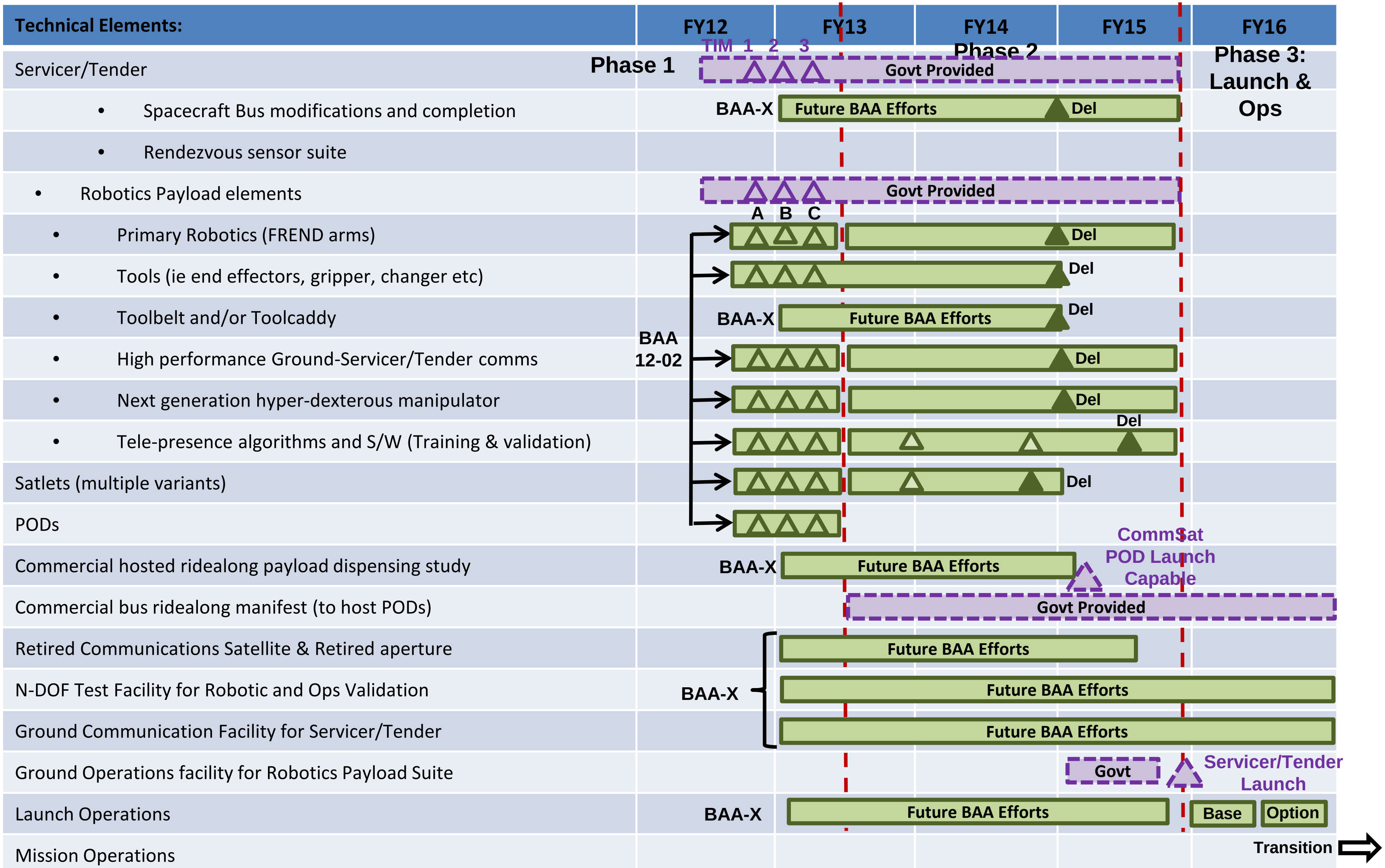
- PODs (Payload Orbital Delivery system).
- Satlets (contained within PODs containers).

On Earth

- Ground Communication Facility for Service/Tender.
- Ground Operations Facility for Robotics Payload Suite.
- N-DOF Test Facility for Robotic and Ops Validation.



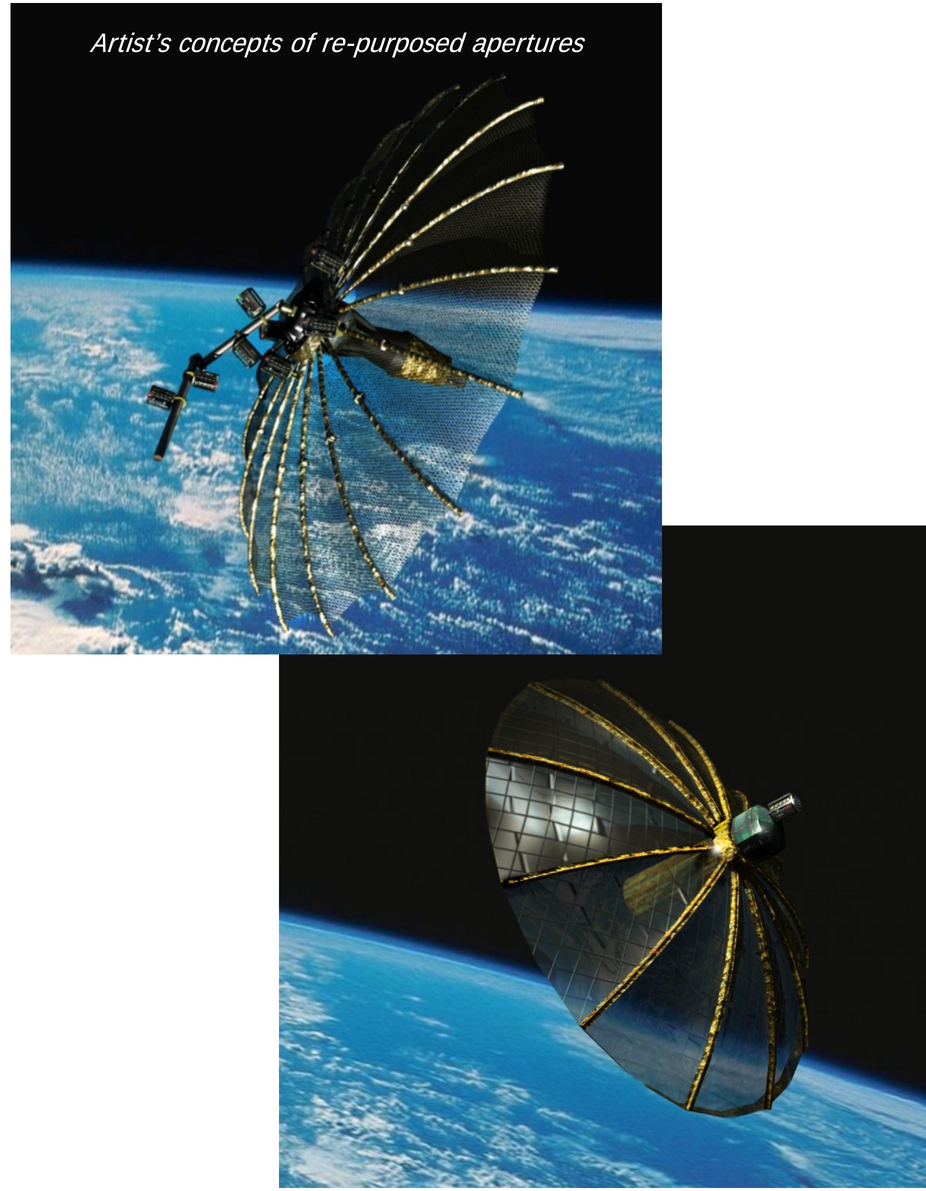
Notional program demonstration timeline



Summary

DARPA's Phoenix program encourages,

- new methodologies and technologies to foster the ability to re-use high value components in space
- new methodologies to lower the cost of DoD operations in space
- re-defining how satellites are designed and built, to on-orbit "assembly"
- upgrading satellites faster to accommodate new electronics, technologies.
- non-traditional space suppliers and players to enter space market through dispensed COTS hosted payload delivery.
- national and international dialogue on acceptance of a servicing culture for space



Artist's concepts of re-purposed apertures