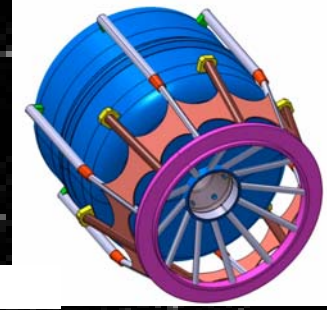


HERMES On-Orbit Servicing

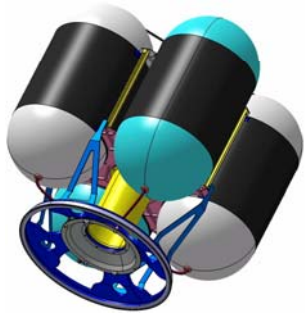


Optimal System Architecture
enabling an
Optimal deployment path

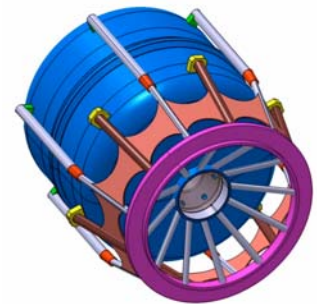
Charis S. Kosmas

Photo courtesy of cover page picture ESA//ESOC

To : UN-COPUOS

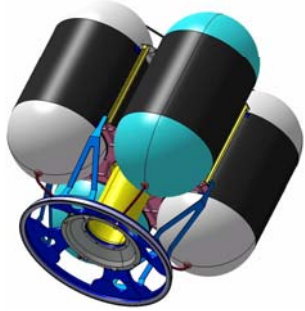


Objective

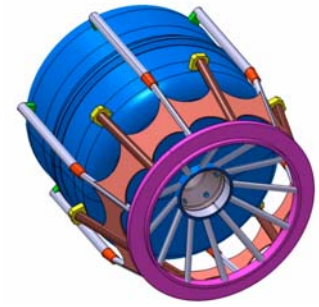


The Project mainly aims at reducing the operational cost of satellite services provision for making them available to larger parts of population especially in countries with limited economic resources.

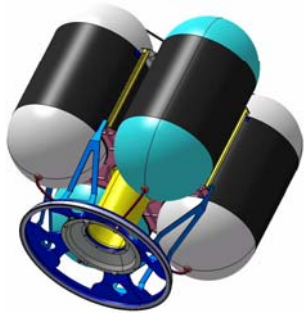
This is possible taking into account the fact that currently the price elasticity of demand for satellite services is 5%.



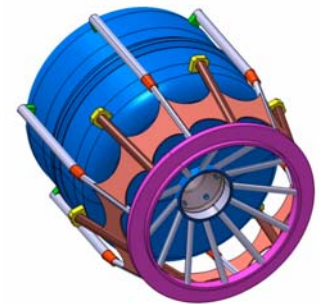
Implementation strategy



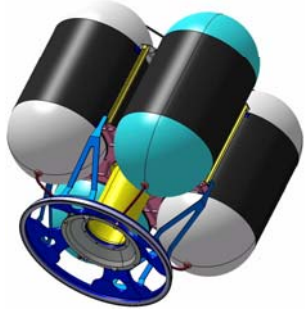
- The Project is focusing on the space segment and in particular on methods of reducing the cost of space assets through adaptation, improvement and optimization of the **whole existing chain** of infrastructure currently needed by the satellites (from launcher, to the upper stage, to the apogee kick motor, to the satellite) and by **inventing** new types of space vehicles to extend the current space capabilities.



The problem in GEO ring: Debris and revenue loss

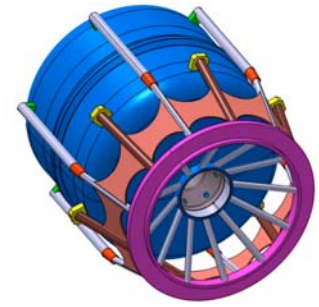


- 50 % (9 / year commercial s/c) die of anomalies resulting in creation of space debris. In-situ Inspection could facilitate fast analysis of situation/solution = **136.5 M€**
- 50 % (9 / year) die of fuel depletion at the designed lifetime. Some 3-4 years life extension would be desirable. Lost revenue = $9 \text{ s/c} \times 30 \times 1.5 \times 0.7 \text{ M€} = \mathbf{245 \text{ M€/y}}$.

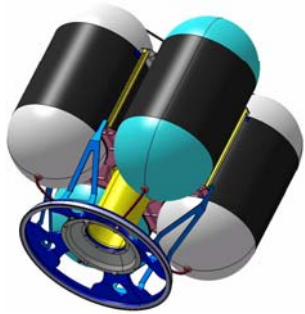


Services needed

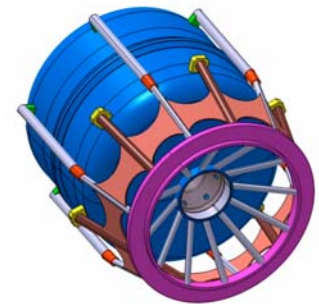
1



- 1 Inspection:** Of alive satellites to assist commissioning and characterisation / calibration. Of sick/dead satellites to determine status (anomaly resolution). Of debris to determine re-orbit feasibility.
- 2 Transportation:** To re-orbit a Client satellite (CS) at EOL, or re-orbit apogee-kick-motors after orbit injection.

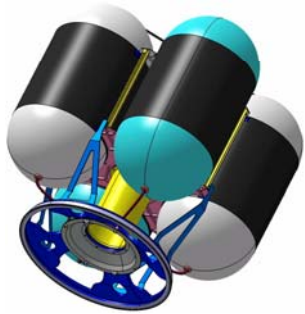


Services needed 2



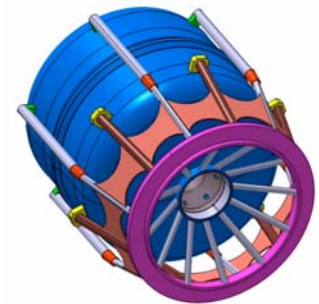
3 Refueling: To enable new s/c to be launched with small fuel supplies (low manufacturing and launch cost) and let decision on additional fuel, according to operational life and health status, to be taken at later stage.

4 Preventive / recovery maintenance:
To replace outdated / faulty elements ...



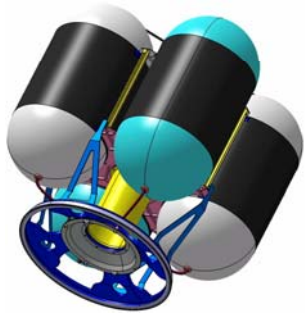
Services needed

3

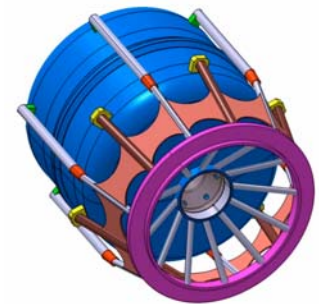


... to enable the manufacturing of satellites that are capable to capitalize faster on technology developments.

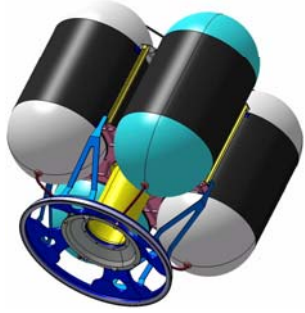
5 Assembly in space of large structures to enable availability of structures that normally do not fit in an efficient manner under the fairing constraints / launch environment (high g, acoustic vibr.).



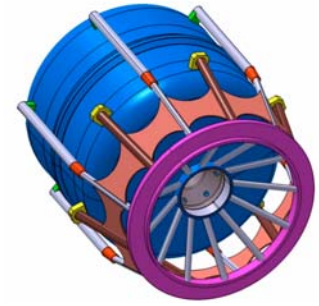
Innovative System Architecture



- **Five synergetic elements:**
 - The Utility Base (UB)
 - The Utility Agent (UA)
 - The Escort Agent (EA)
 - The Engine Module (EM)
 - A new family of apogee kick motors
- **And maximum utilization of existing satellite assets:**
 - Use of up-link of existing CS to dock.
 - Use Telecommand link to control EM.

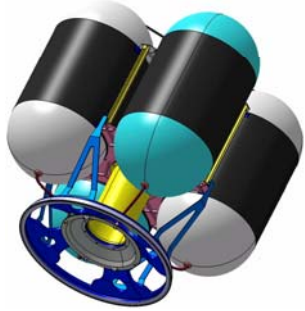


**New concepts.
Breakthrough
efficient solutions**

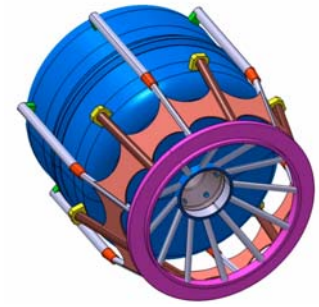


Patent Pending concepts:

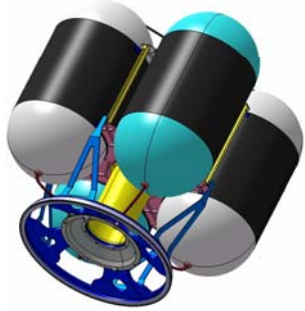
- for docking process simplification (apparatus and method)
- for control channel for Engine Module
- for a capturing apparatus
- for a heavy duty double-functional reusable apogee-kick-motor (AKM).



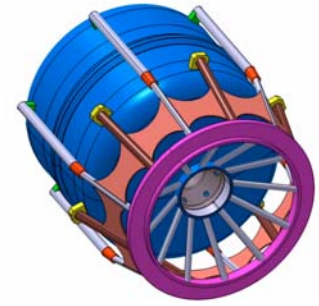
The Utility Base (UB)



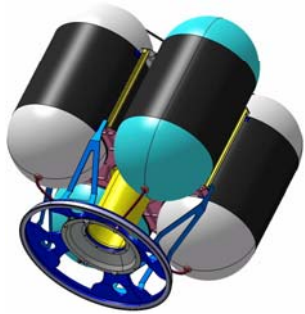
- **Size:** Large object in comparison to current satellites (mothership).
- **Function:** Resource & Spares provider and resting place to UA, EM, EA (Fuel, pressurant gas, High bandwidth link).
- **Positioning:** Station keeping in a busy area at the GEO Ring level with some inclination (TBD) for optimal traffic.



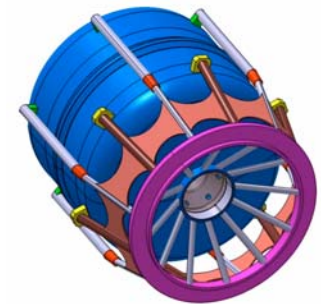
The Utility Agent (UA)



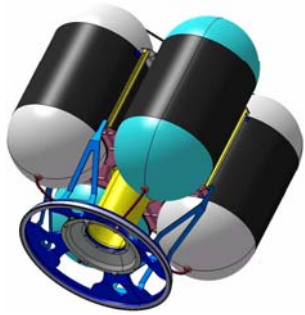
- **Size:** Small 150 to 250 kg.
- **Function:** Refuellable Tug vehicle, with capability to perform teleoperated docking to a CS, enabled by a real time camera signal which is relayed through the CS. Inspection.
- **Positioning:** Navigate from UB to client spacecraft(s) and back for refueling.



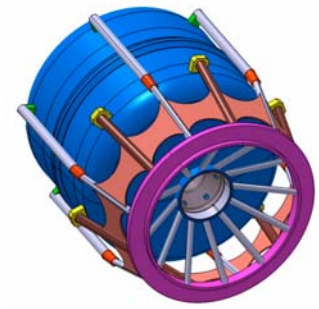
Engine Module (EM)



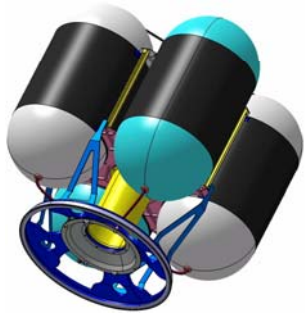
- **Size:** very small 40-70 kg,
- **Function:** Perform continuous N-S stationkeeping of a client spacecraft. Control is direct from the CS through listening to the telemetry of the CS.
- **Position:** Attached on a CS. Porting to spacecraft and docking is performed by a UA.



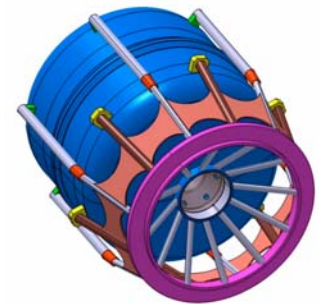
Escort Agent (EA)



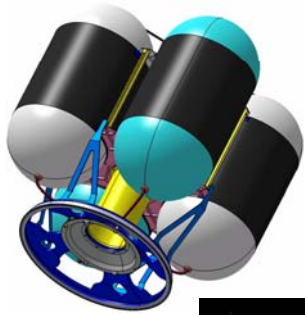
- **Size:** Tiny 7-15 kg.
- **Function:** Perf. Risk free, close-up camera inspect of a CS at all surfaces from one side to the other. Relay signal through the CS or the UA.
- **Positioning:** Ported to the inspection target by a UA. Navigates around the CS to inspect / assists UA in docking.



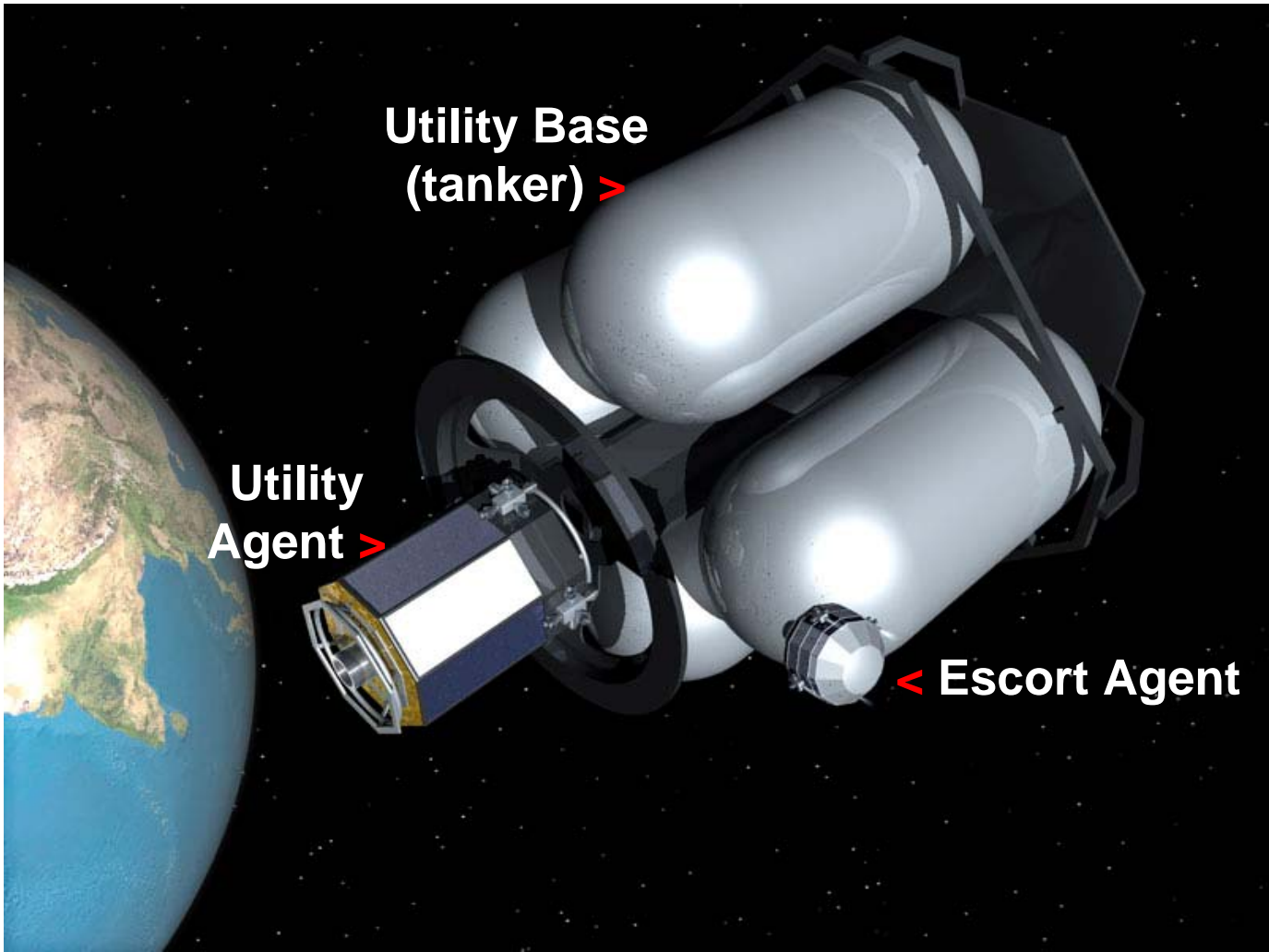
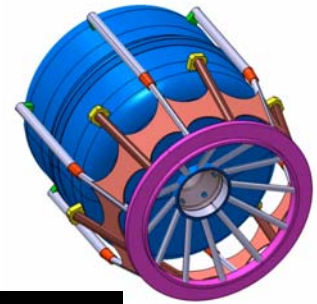
Utilization of existing Satellite assets

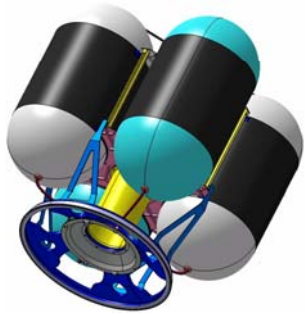


- **Up-Link channels** of CS: Utility Agent may use Up-link channel of client spacecraft, in proximity, to relay real-time camera signal during docking/inspection. Escort Agent does likewise.
- **Tecommand** of CS: May be used to port towards the EM the required commands through the ***Echo*** command.

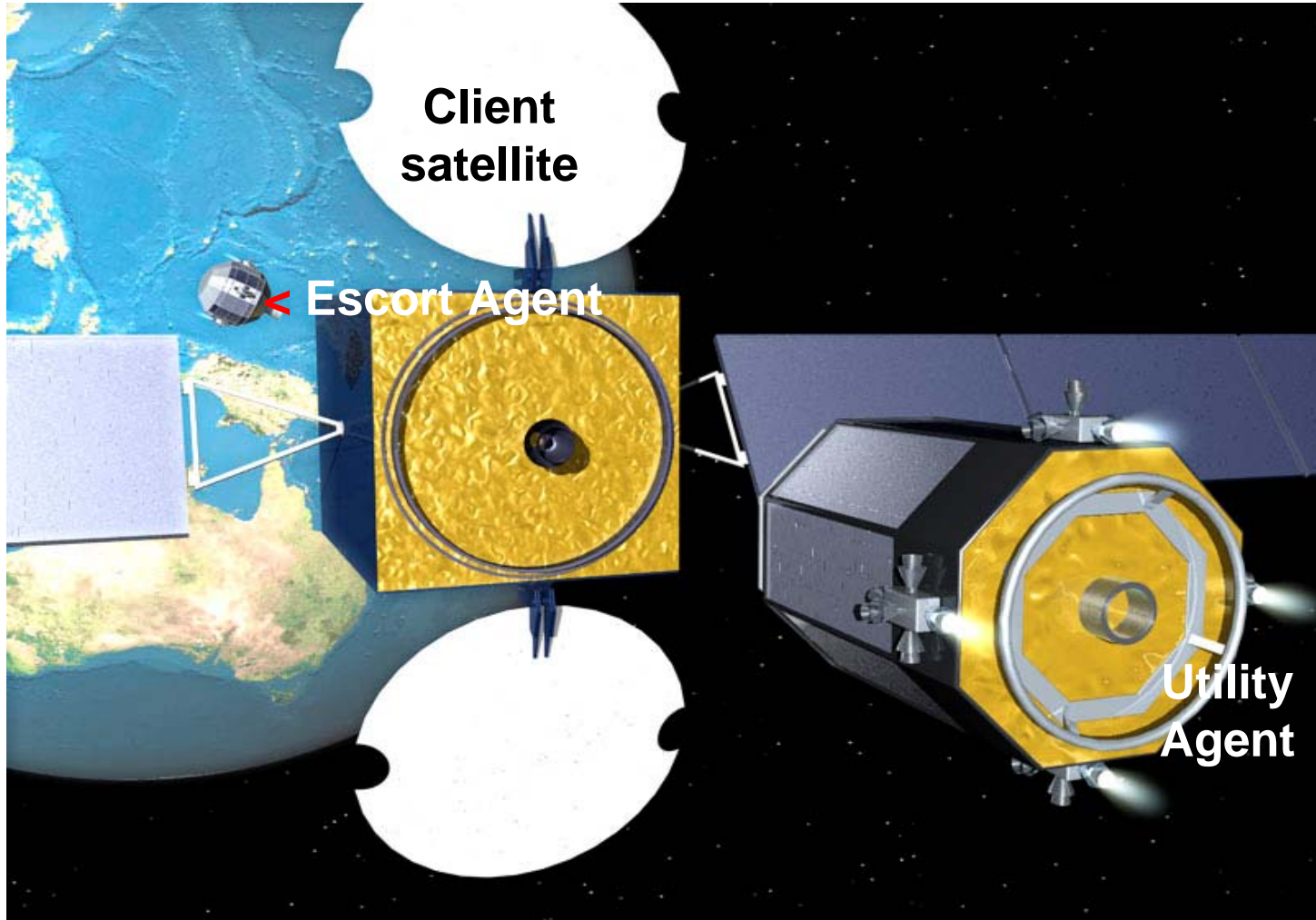
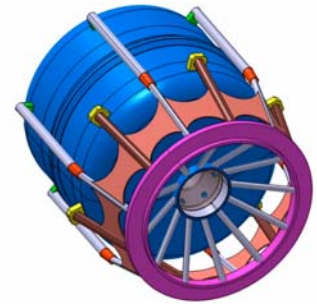


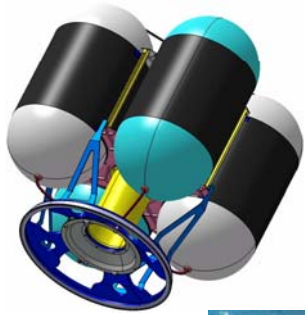
UB with UA with EA



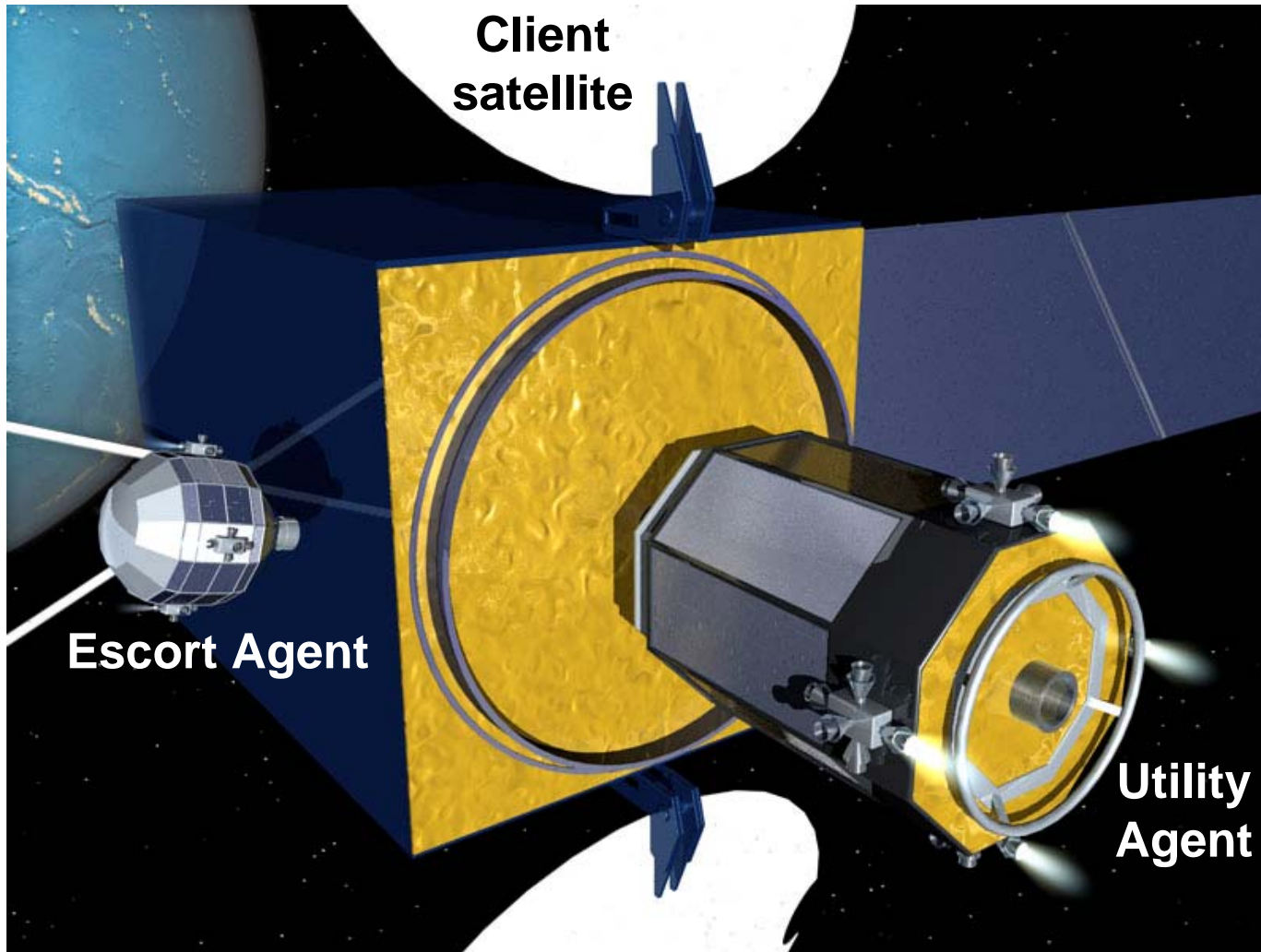
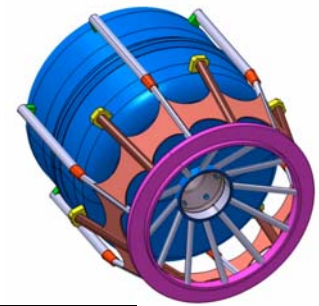


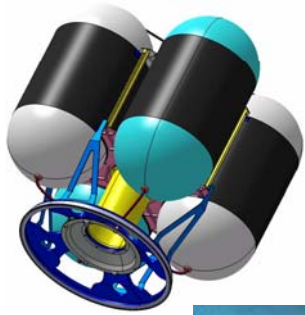
UA with SC with EA



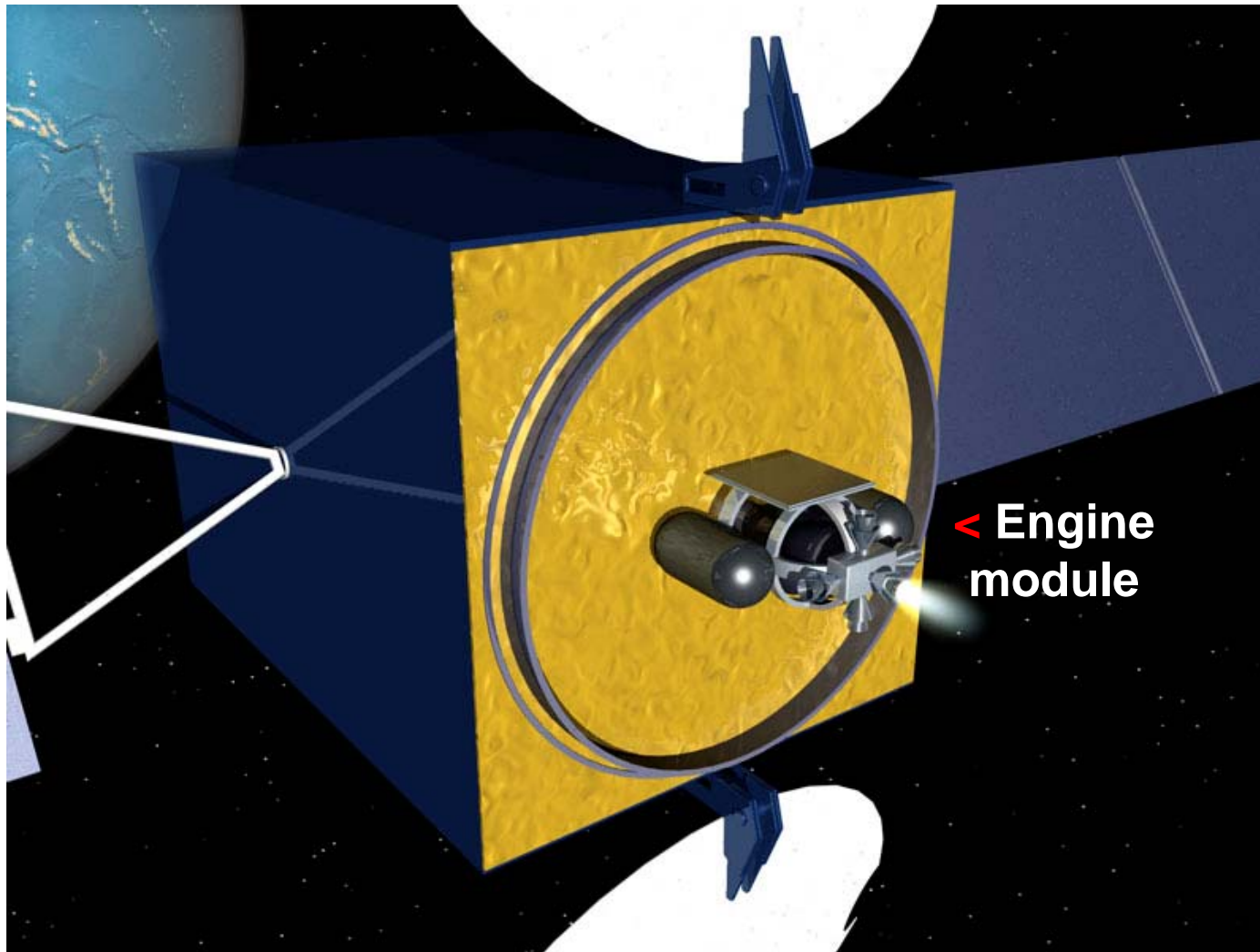
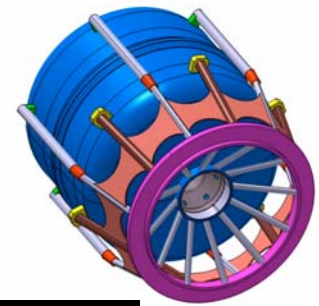


CS with UA with EA

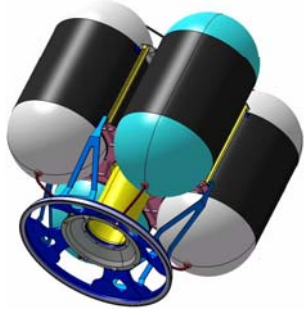




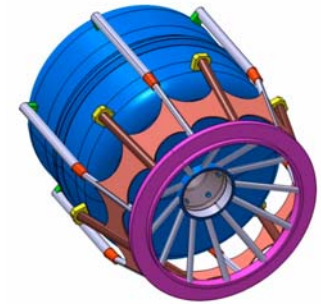
satellite with EM



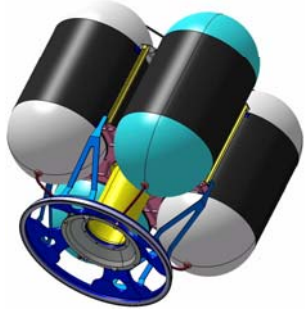
< Engine module



Cross element characteristics



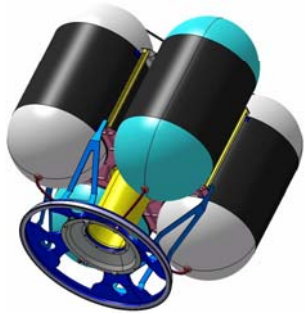
- **Segregated functionality**
 - Elements have complementary functions
 - UB High level of resources
 - UA High mobility
 - EM controlled by client s/c, cheaper possible
 - EA lightest, harmless, close-up inspection
- **Cascade dependency of three layers**
 - **UB>UA>EM**
 - **UB>UA>EA**



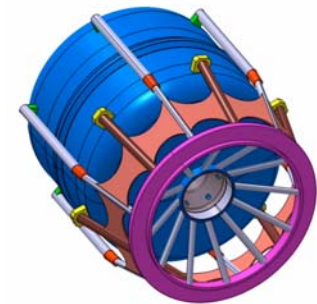
Internal element characteristics



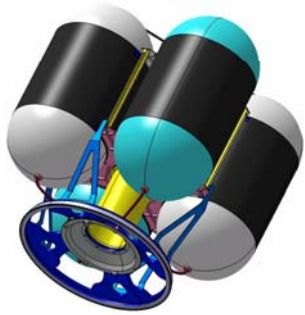
- **Elements with high reusability**
 - ALL refuellable: UB, UA EM, EA, AKM
 - Repairable as possible.
 - Disposable tidily / canibalizeable.
- **Low redundancy of subsystems**
 - compensated by redundancy of units and repairability
 - To keep the build and test cost low and complexity at low to ease repairability.



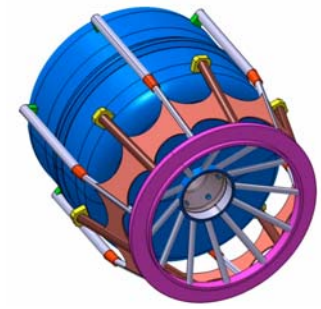
Deployment Schedule Demo + 4 Phases



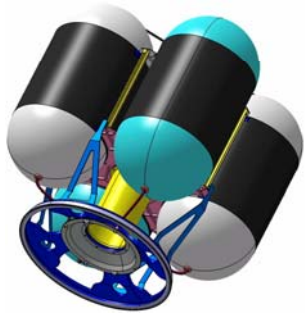
To : UN-COPUOS



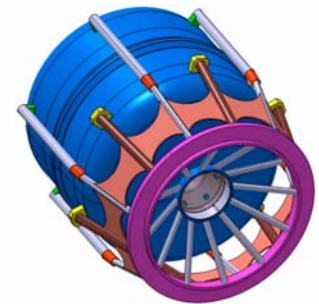
Optimal deployment



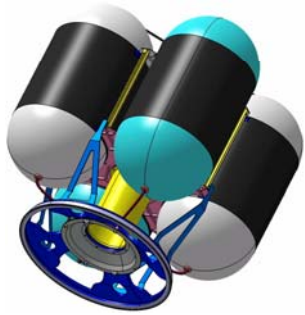
- **Start from GEO**
 - that can use best the existing satellite assets
 - has the larger market.
 - Most crowded
- **Use a phased deployment and opportunities as they come.**
 - **One opportunity is identified now !**



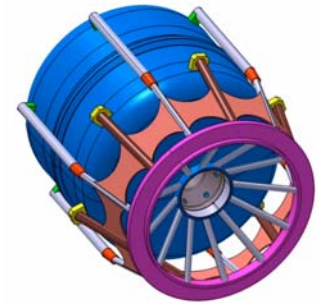
OOS kick-start Scenario



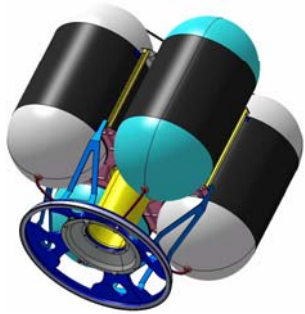
- One **tanker spacecraft** could be launched by the Ariane-5 ECA flight, to a high perigee GTO orbit.
- One **chaser spacecraft** (UA) could be launched within 3 years time to catch the tanker, revive it and use part of fuel to push it to GEO and the surplus fuel to perform missions (debris clean-up ...).



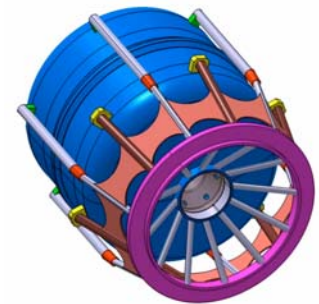
What is the tanker S/C (1)



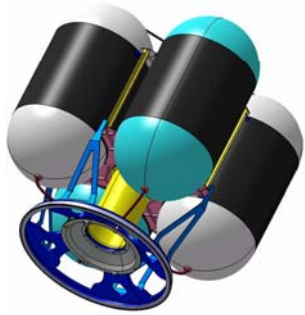
- Totally passive fuel storage system.
- Contains 3 t. storable propellants.
- Has “easy to catch” attitude behaviour.
- Has passive docking interface.
- Can be produced in 3-4 months.
- Can survive long time unattended.



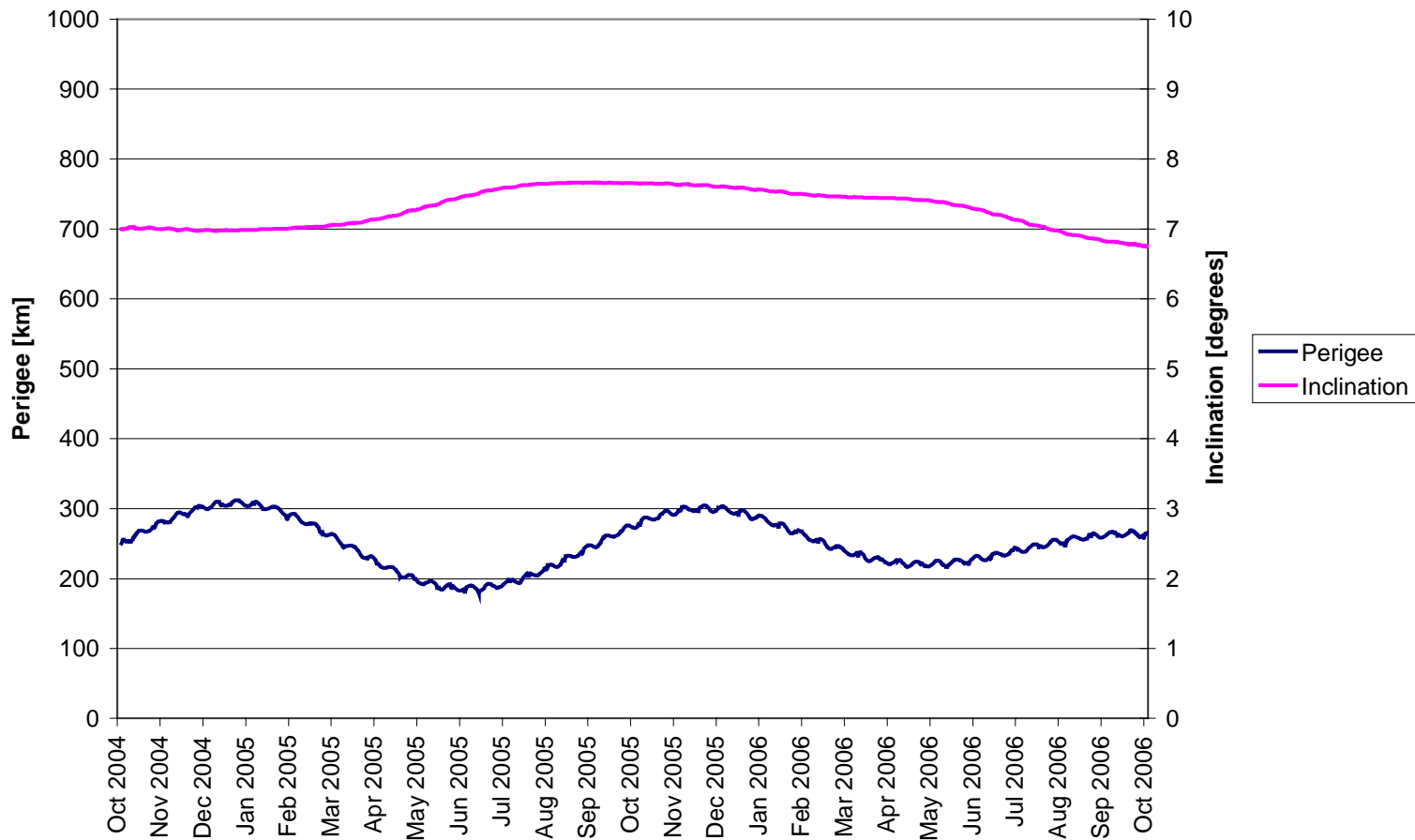
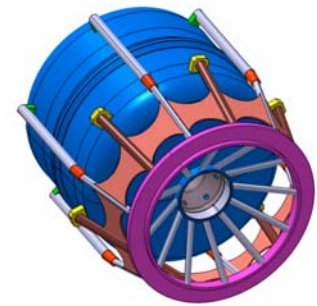
What its use could be?

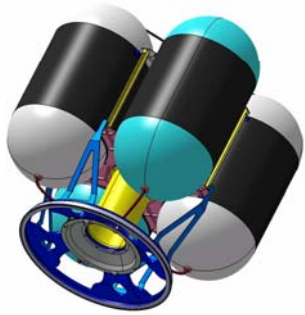


- To be the target of a chaser spacecraft that we call Utility Agent (**UA**).
- To demonstrate passive docking capability.
- To provide fuel to the **UA**. (fuel sufficient to reach GEO with 300 to 900 kg surplus for further service demonstrations).
- Is a primitive early substitute of the UB.

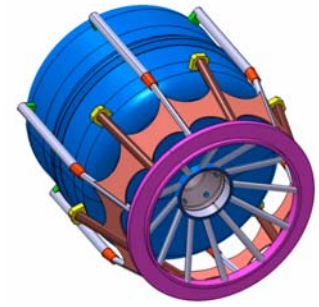


What orbit GTO ?

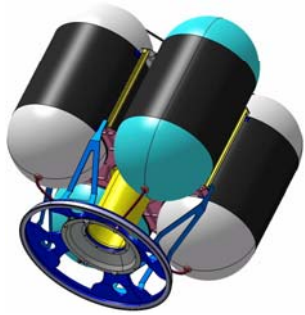




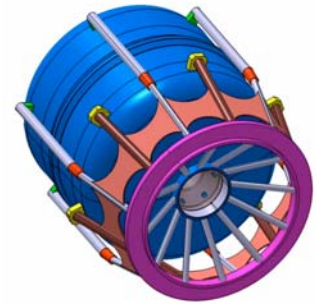
High perigee GTO characteristics



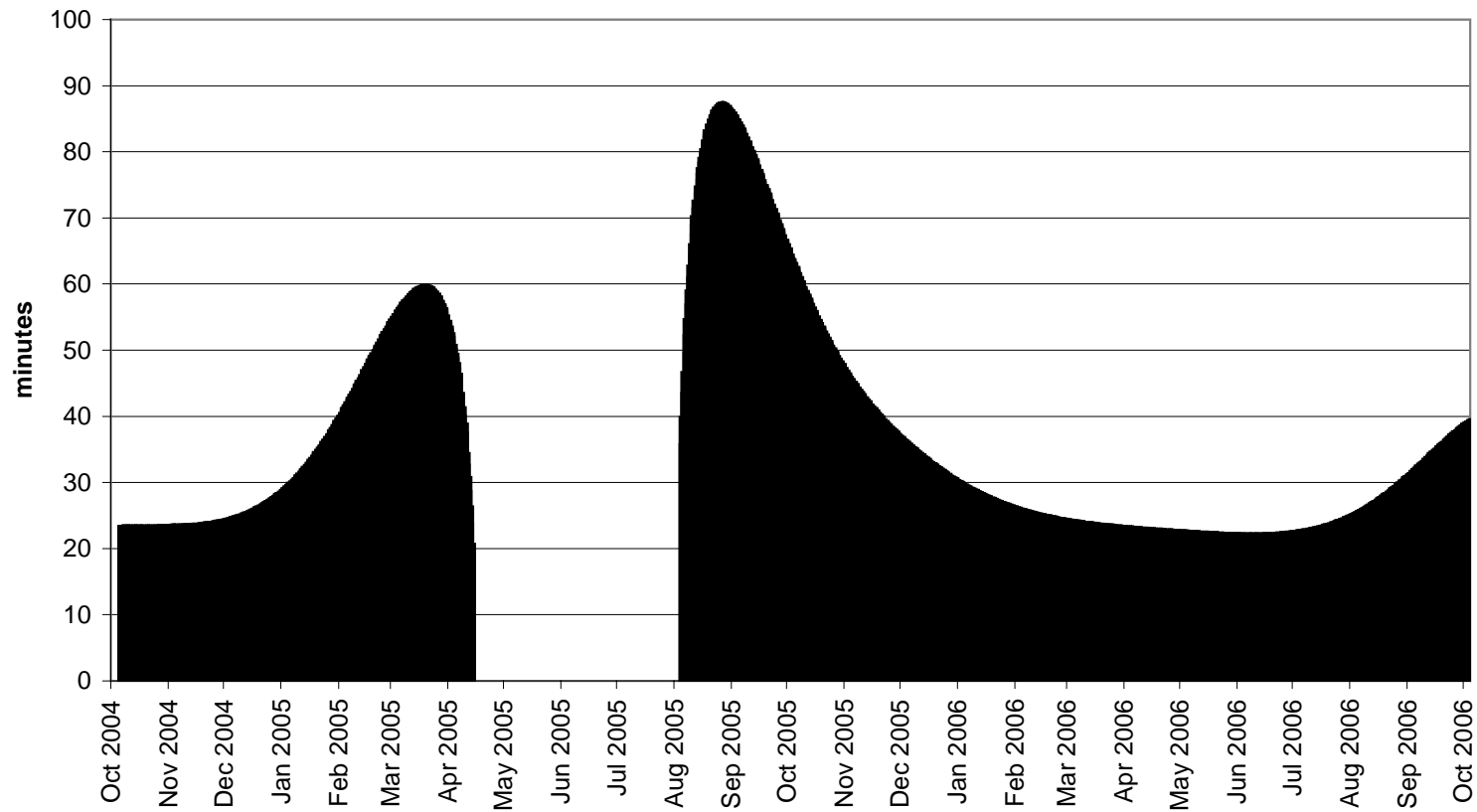
- Perigee height has periodic oscillation but within acceptable limits.
- Inclination evolution is in a narrow band.

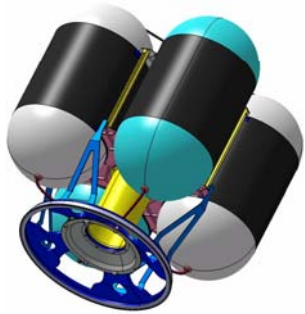


Why frozen ?

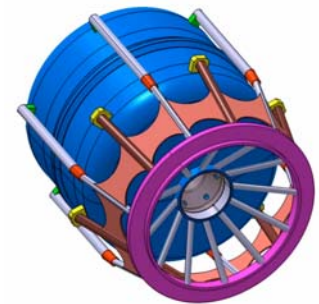


Earth Total Eclipse Duration

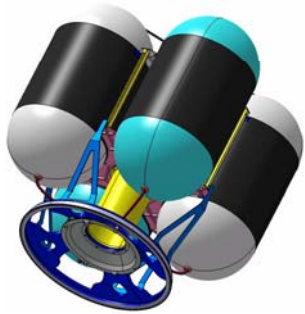




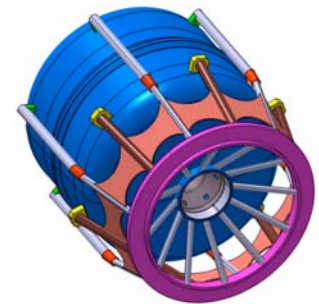
FAQ 1



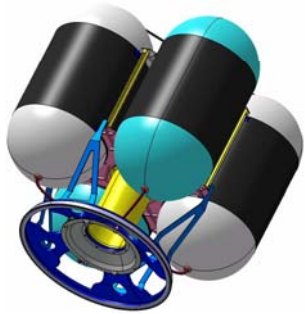
- **Isn't it dangerous to Launch ?**
- Passive nature (no power to activate valves or heaters, no pyros, no EMC compatibility issue) ensures safety.
- No catalyst on board to enable ignition.



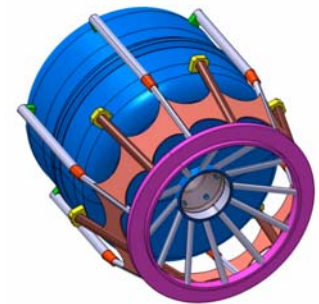
FAQ 2



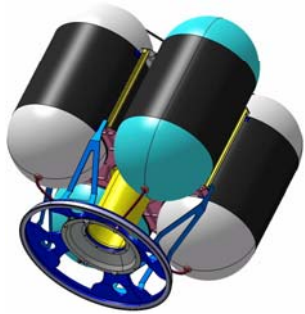
- **Isn't it dangerous to "fly around" long time uncontrolled ?**
- This is a practice currently followed by many operational spacecraft (some NOAA s/c and some telescopes) not a first.
- Fuel availability and OOS could stop this phenomenon



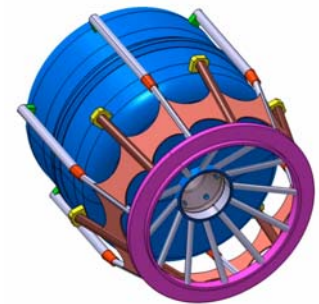
FAQ 3



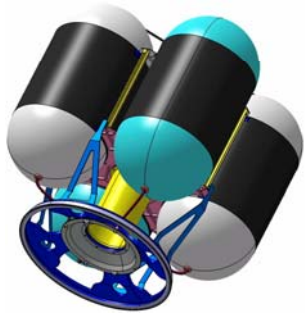
- **Is the tanker S/C feasible ?**
Design available, team to realize available.
- **Is the Utility Agent feasible ?**
Patent pending solution for final docking phase simplification (apparatus & method). Positive feedback from the patent office.



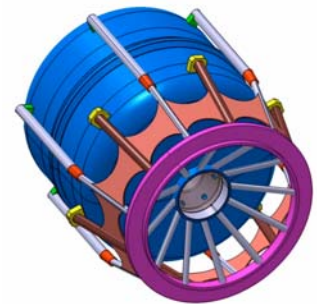
Why start now ?



- Opportunity to demonstrate **aggressive attitude to trouble shooting**, which is the essence of OOS.
- Relatively large capacity available (3.7 t) calls upon completion of the task (large incentive).



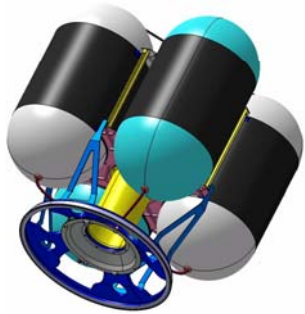
The benefit to GEO Ring USERS >...



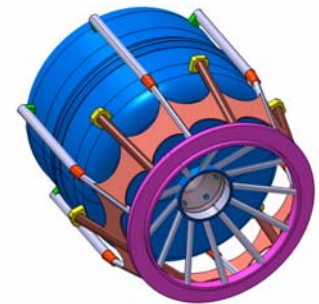
OOS will get finally a kick start date for performing:

- **PHASE 0 (Demo)**

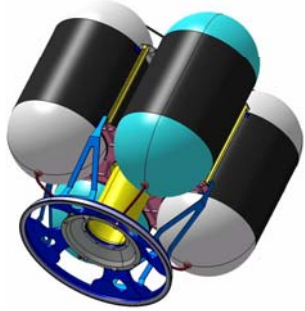
- Inspection in-situ;
- Transportation of spent Apogee Kick Motors and upper stages to grave yard;
- Transportation of spent satellites to grave yard but also tidely (gathered);
- Inclination correction (repetitive) extending lifetime;
- Demonstrate / optimise refuelling process;
- Cheap satellites will become readily available;



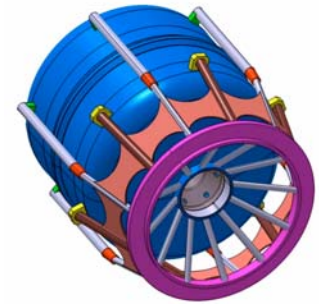
... Other benefits
to GEO Ring
USERS >...



- **PHASE 1 (full deployment, at 360⁰)**
 - Small refuelable satellites will emerge. Small entry cost to new entrants.
 - Refuelling of CS will be available only on the UB, or could be transported by UA given kinetic energy (Δv).
 - Bulk fuel quantities available on cargo basis for cheap refueling of servicing fleet.

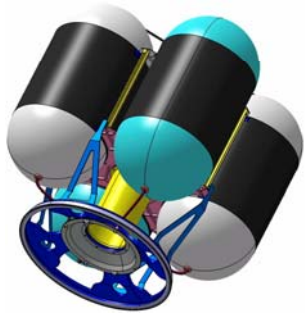


... Other benefits
to GEO Ring
USERS >...

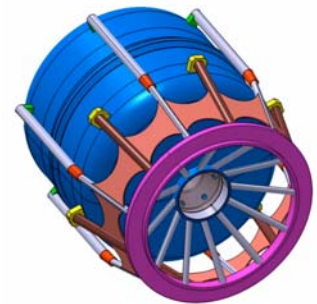


- **PHASE 2 (Refuelling to CS)**

- The refuelling service will be available at low cost to the CSs in-situ, by means of refuelling capable UAs.
- Modular satellites with replaceable elements will start to emerge. Cost will drop due to reduced need for long life components due to replaceability option.
- Satellites of reduced redundancy will further emerge and squeeze cost also due to emerging replaceability option.

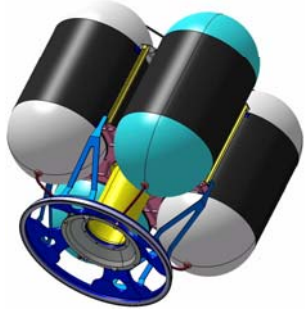


**... Other benefits
to GEO Ring
USERS >...**

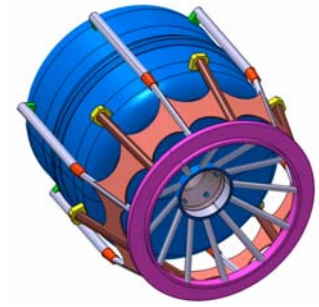


- **PHASE 3 (Maintenance demo & operations)**

- Maintenance service will become available in situ for replacing modules, on the UB for deeper Unit Level interventions (momentum wheels, battery packs,...)
- Progressive maintenance capability to lower levels in the engineering hierarchy (subassembly level, Part level).

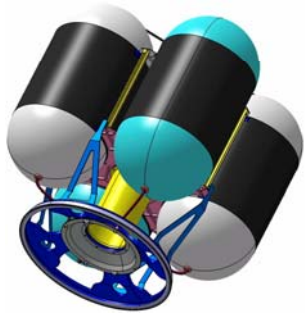


... Other benefits to GEO Ring USERS .

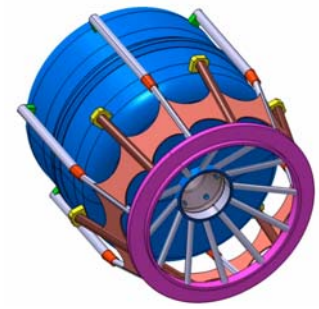


- **PHASE 4 (Assembly)**

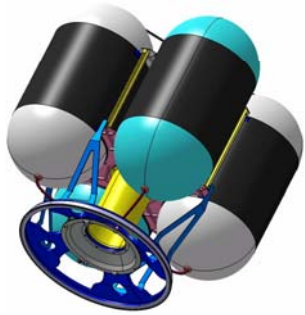
- Large long duration reusable structures like antenna reflectors will become available reducing the need to launch them with the spacecrafts.
- Cost / performance ration will be reduced to record low levels.
- Mass marker services will become available to low income customers globally (satellite mobile phones,) and moon bound & Lanrgange points projects will emerge.



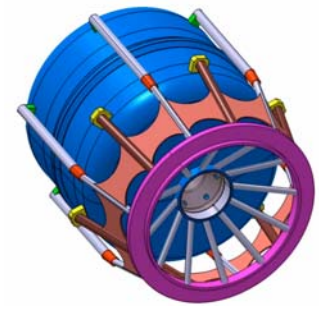
Status



- Continue to submit aggressively patent applications.
- Continue to develop partnerships (MoUs, co-operation Agreements).
- Continue to investigate opportunities on qualification flights (ESA, ...).
- Develop marketing and sponsor offerings with Media firms.
- Ready to perform the TANKER mission
- **Target to perform space debris clean-up in the nearest future (3 years), for demo.**



Thank You



**For more details on the project
HERMES**

- **see Web site :**

www.GEO-Ring.biz

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