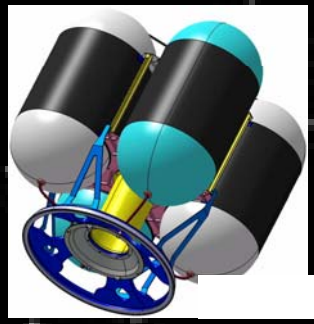
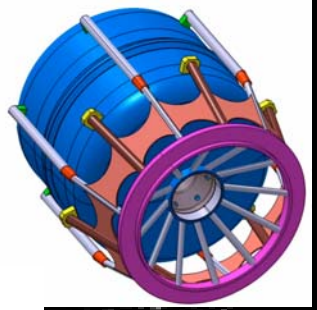


HERMES
On-Orbit Servicing



Optimal System Architecture enabling an Optimal deployment path

Charis S. Kosmas

Photo courtecy of cover page picture ESA//ESOC

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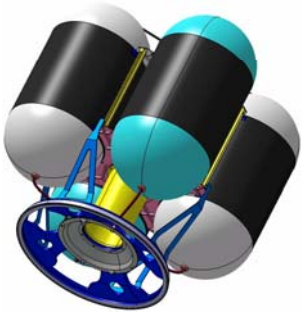
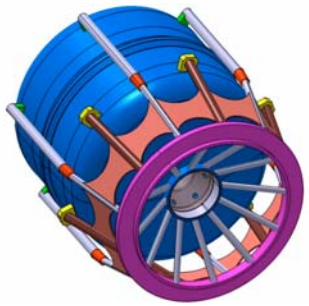
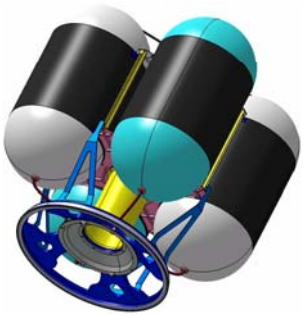


Objective

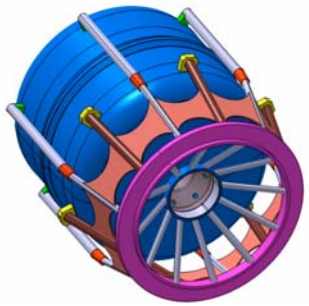


The Project mainly aims at reducing the operational cost of satellite services provision for making them available to larger parts of population especially in countries with limited economic resources.

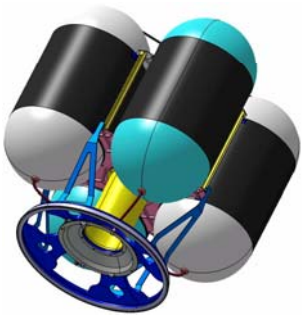
This is possible taking into account the fact that currently the price elasticity of demand for satellite services is 5%.



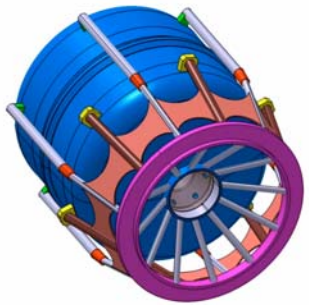
Implementation strategy



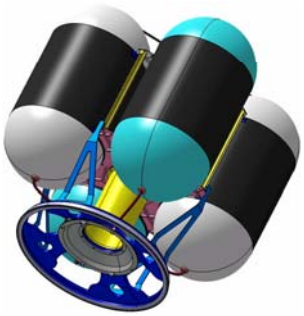
- The Project is focusing on the space segment and in particular on methods of reducing the cost of space assets through adaptation, improvement and optimization of the **whole existing chain** of infrastructure currently needed by the satellites (from launcher, to the upper stage, to the apogee kick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



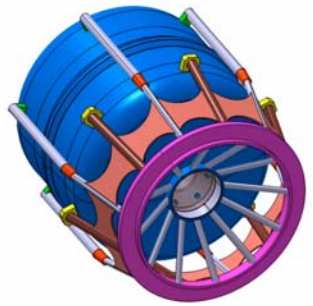
The problem in GEO ring: Debris and revenue loss



- 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 extention would be desirable. Lost revenue= 9s/c x 30x1.5x0.7 M€=**245 M€/y**.

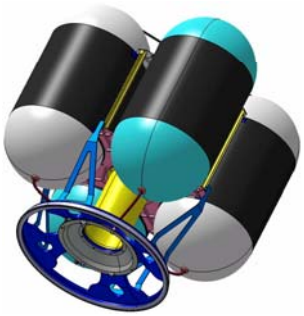


Services needed 1

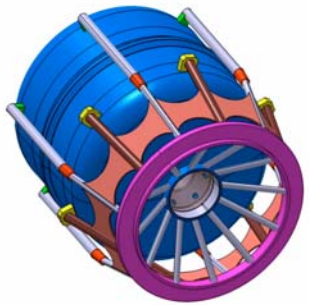


1 **Inspection:** Of alive satellites to assist commissioning and characterisation / callibration. Of sick/dead satellites to determine status (anomaly resolution). Of debris to detemine re-orbit feasibility.

2 **Transportation:** To re-orbit a Client satellite (CS) at EOL, or re-orbit apogee-kick-motors after orbit injection.

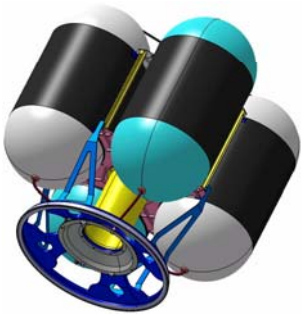


Services needed 2

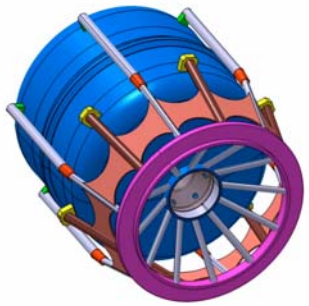


3 **Refueling:** To enable new s/c to be launched with small fuel supplies (low manufacturing and launch cost) and let decision on additional fuel, according to operational life and health status, to be taken at later stage.

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

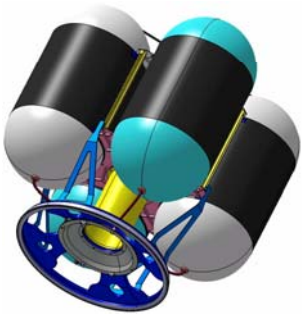


Services needed 3

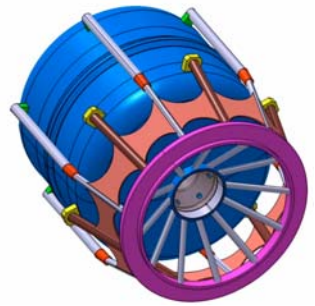


… to enable the manufacturing of satellites that are capable to capitalize faster on technology developments.

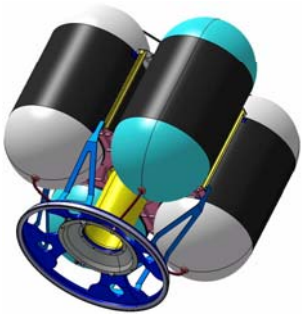
5 **Assembly** in space of large structures to enable availability of structures that normaly do not fit in an efficient manner under the fairing constraints / launch environment (high g, accoustic vibr.).



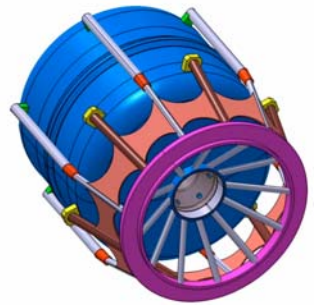
Innovative System Architecture



- **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.**

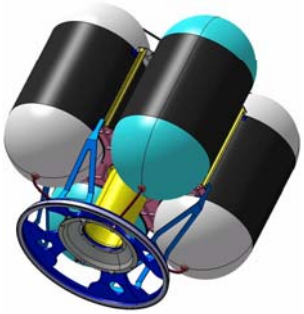


New concepts. Breakthrough efficient solutions

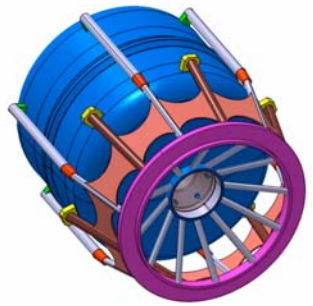


Patent Pending concepts:

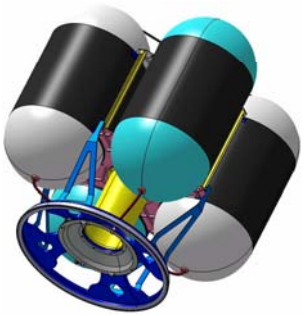
- for docking process simplification (apparatus and method)
- for control channel for Engine Module
- for a capturing apparatus
- for a heavy duty double-functional reusable apogee-kick-motor (AKM).



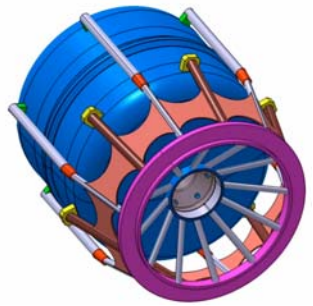
The Utility Base (UB)



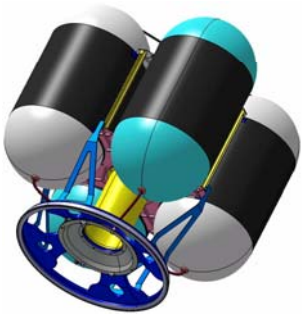
- **Size:** Large object in comparison to current satellites (mothership).
- **Function:** Resource & Spares provider and resting place to UA, EM, EA (Fuel, pressurant gas, High bandwidth link).
- **Positioning:** Station keeping in a busy area at the GEO Ring level with some inclination (TBD) for optimal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



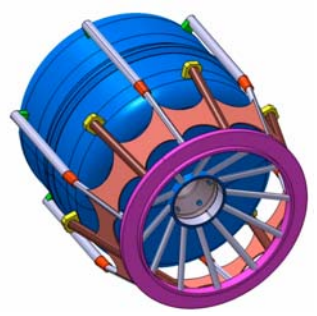
The Utility Agent (UA)



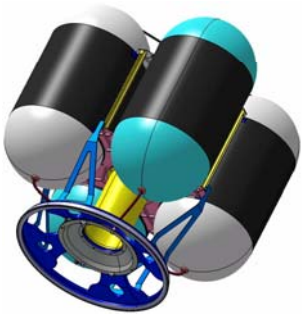
- **Size:** Small 150 to 250 kg.
- **Function:** Refuellable Tug vehicle, with capability to perform teleoperated docking to a CS, enabled by a real time camera signal which is relayed through the CS. Inspection.
- **Positioning:** Navigate from UB to client spacecraft(s) and back for refueling.



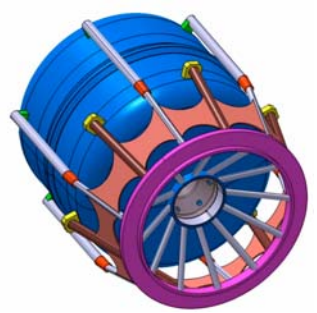
Engine Module (EM)



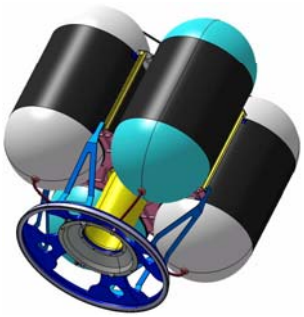
- **Size:** very small 40-70 kg,
- **Function:** Perform continouous N-S stationkeeping of a client spacecraft. Control is direct from the CS through listening to the telemetry of the CS.
- **Position:** Attached on a CS. Porting to spacecraft and docking is performed by a UA.



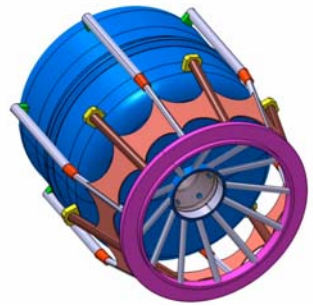
Escort Agent (EA)



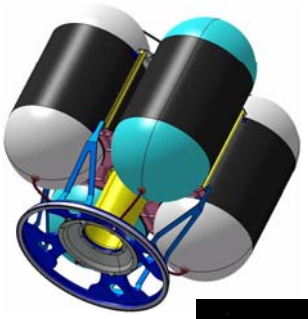
- **Size:** Tiny 7-15 kg.
- **Function:** Perf. Risk free, close-up camera inspect of a CS at all surfaces from one side to the other. Relay signal through the CS or the UA.
- **Positioning:** Ported to the inspection target by a UA. Navigates around the CS to inspect / assists UA in docking.



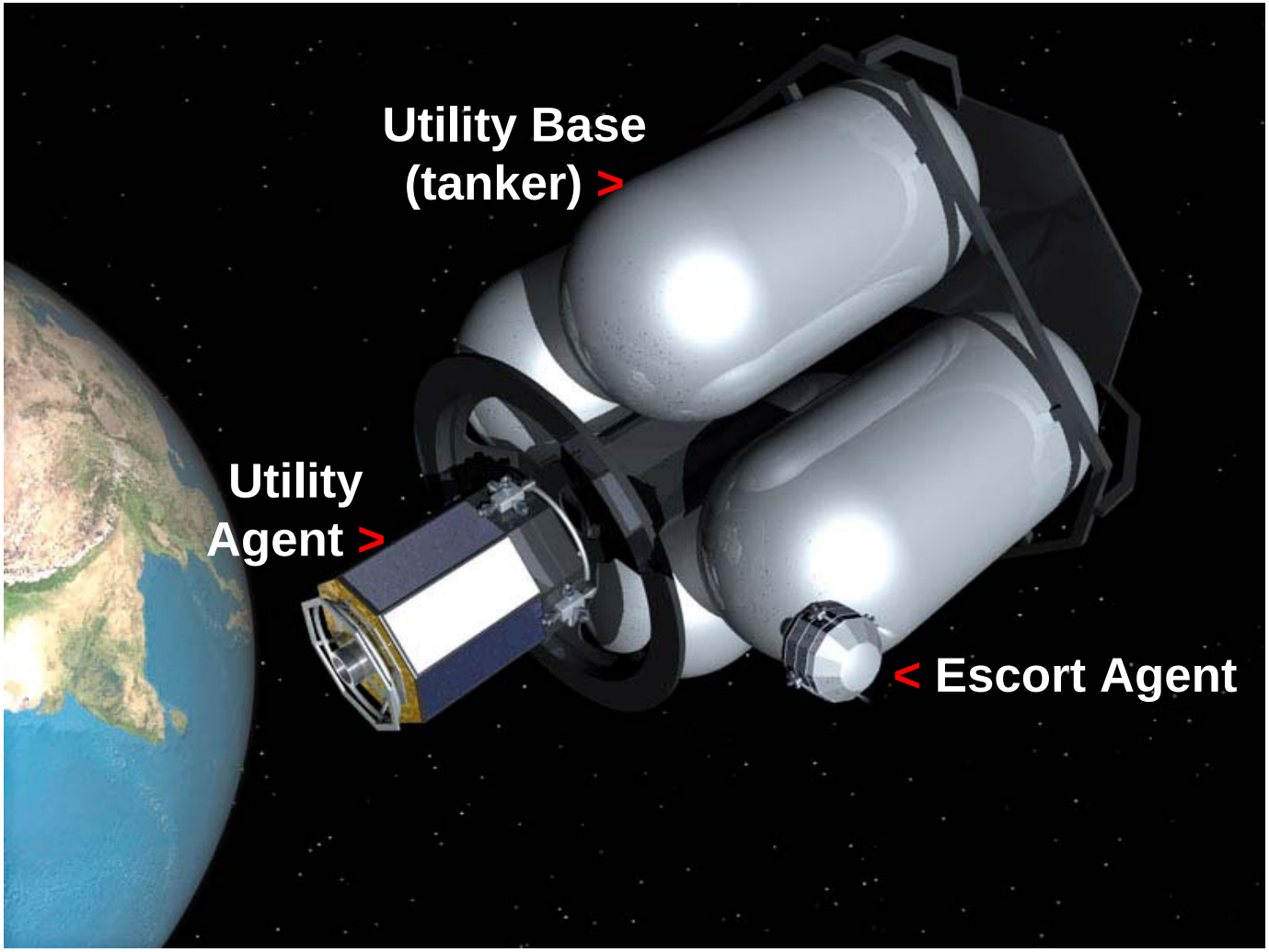
Utilization of existing Satellite assets

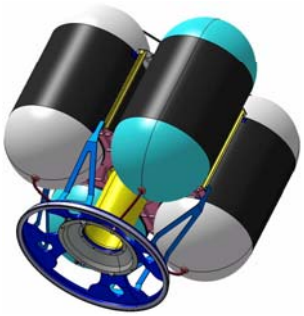


- **Up-Link channels** of CS: Utility Agent may use Up-link channel of client spacecraft, in proximity, to relay real-time camera signal during docking/ inspection. Escort Agent does likewise.
- **Tecommand** of CS: May be used to port towards the EM the required commands through the ***Echo*** command.

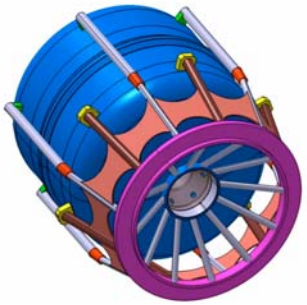


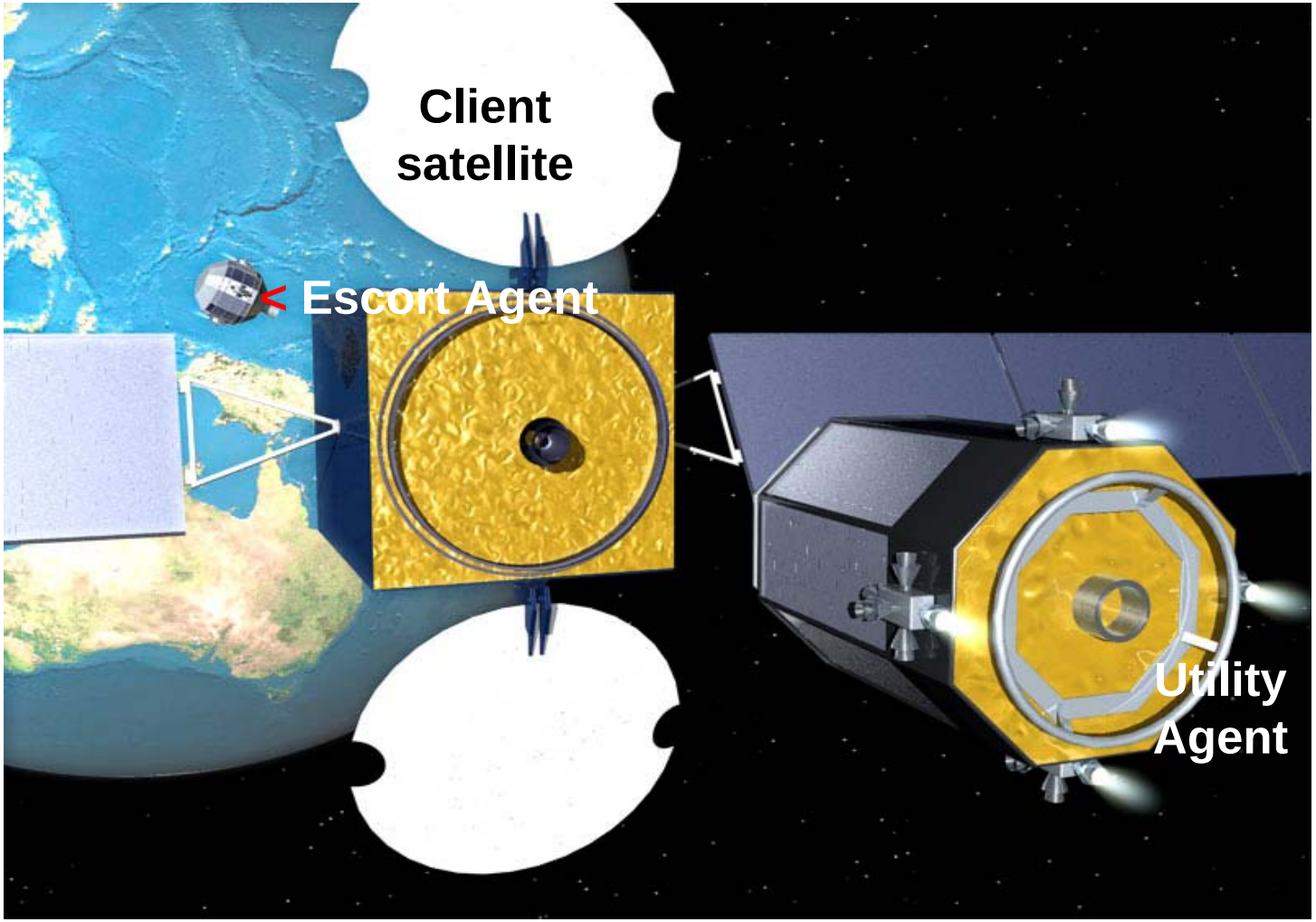
UB with UA with EA

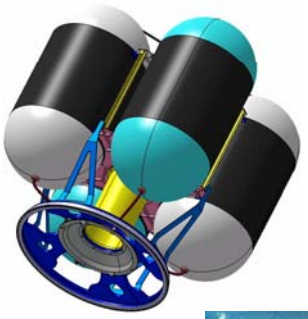




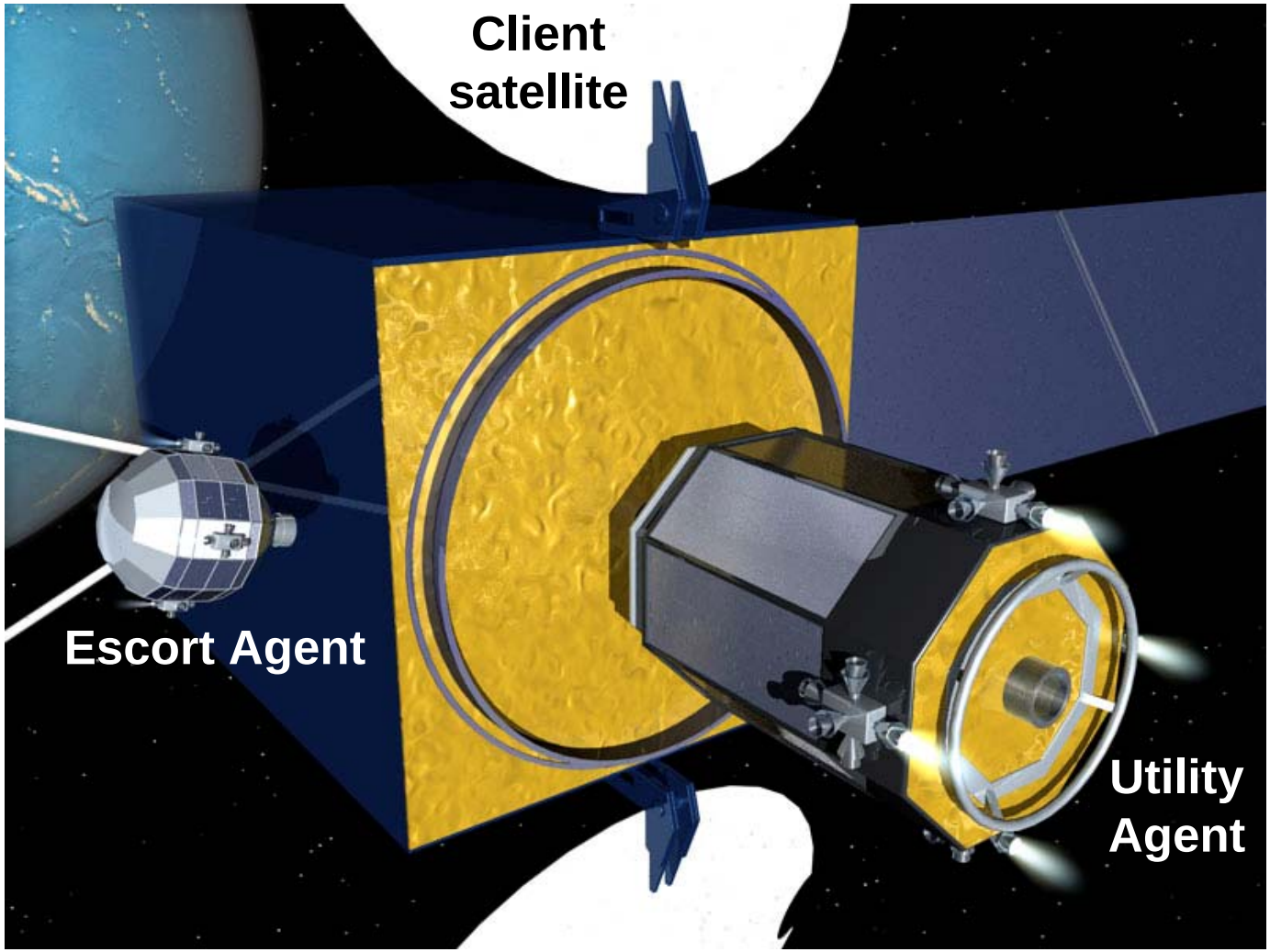
UA with SC with EA







CS with UA with EA



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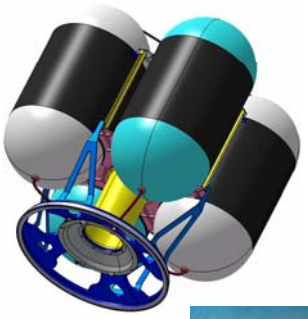
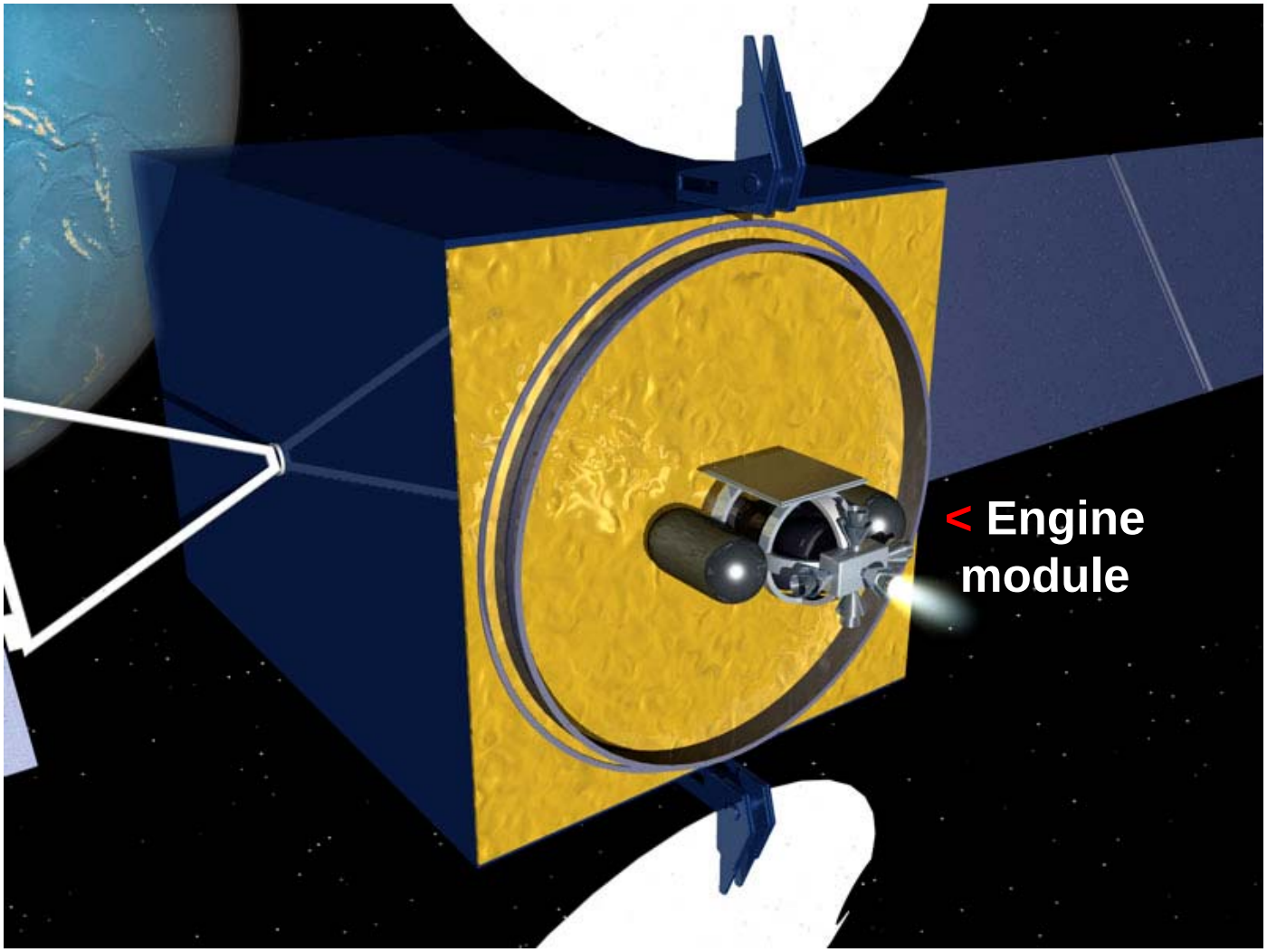


satellite with EM



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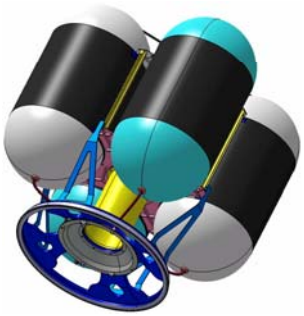
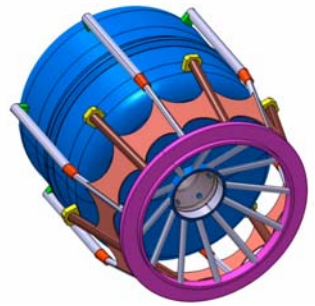
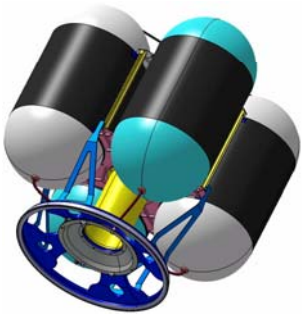


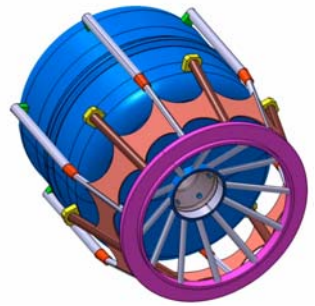
Cross element characteristics



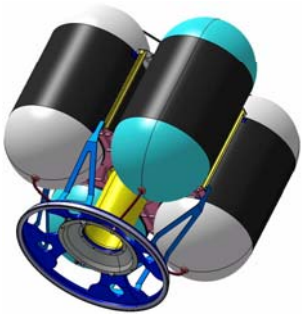
- **Segregated functionality**
  - Elements have complementary functions
    - UB High level of resources
    - UA High mobility
    - EM controlled by client s/c, cheaper possible
    - EA lightest, harmless, close-up inspection
- **Cascade dependency of three layers**
  - **UB>UA>EM**
  - **UB>UA>EA**



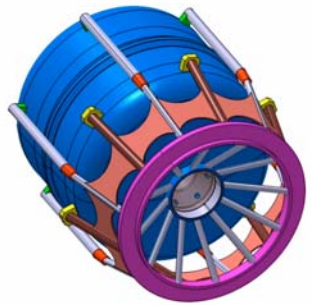
Internal element characteristics



- **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



ID	Duration	
1	66 mo	PHASE 0 demonstration (single area service)
2	0 d	Kick-start 07/06
3	0 d	Launch of demo TANKER 04/10
4	6 mo	Consortium build
5	0 d	Launch of demo UA0 06/07
6	2 mo	Demonstrate UA0 refueling from Tanker
7	1 mo	Demonstrate GTO to GEO raise
8	48 mo	Dev. of UA0 into a Heavy Duty AKM
9	0 mo	Launch of the UA0 embedded into the Heavy Duty AKM 21/07
10	6 mo	Demonstrate UA0 refueling from Heavy AKM
11	48 mo	Build EM, EA
12	0 mo	Launch EM, EA with porting UA 05/01
13	6 mo	Demonstrate Use of EM, EA
14	65.55 mo	PHASE 1 deployment (360 deg service)
15	24 mo	Build bulk fuel supplies element of UB
16	36 mo	Launch bulk supplies store (Ion thrust)
17	48 mo	Routine Transportation intra GEO
18	48 mo	Routine Transportation GTO to GEO
19	12 mo	Retrofit UA, EM, EA
20	24 mo	Launch retrofitted UAs & EAs for UB-1,2,3
24	24 mo	Launch UB-1,2,3
28	32 mo	PHASE 2 Refueling to CS operational everywhere
29	7 mo	Develop refueling capable UA
30	24 mo	Launch refueling capable UA- for UB 1,2,3
34	40 mo	PHASE 3 Maintenance Demo & Operations
35	7 mo	Development of Module replacement UA
36	4 mo	Commissioning of in-situ Module Replacement UA
37	17 mo	Operational in-situ Module Replacement
38	12 mo	Commissioning of retrofitted Module Replacement
39	28 mo	Development of maintenance section of UB (single)
40	0 mo	Launch Maintenance section of UB (single) 28/01
41	12 mo	Commissioning of Maintenance section of UB
42	0 mo	Maintenance base available for routine operations 30/12
43	40 mo	Assembly (Demo - Commissioning - Operational) PHASE 4
44	40 mo	Antenna manufacturing -> GEO & Moon bound constructions

'01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11 '12 '13 '14 '15 '16 '17 '18

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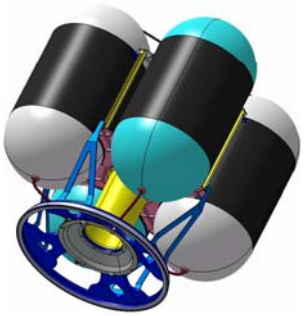
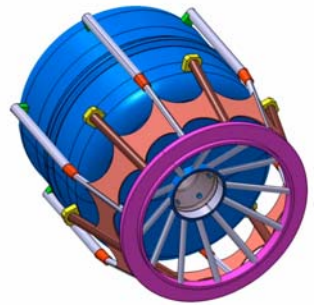
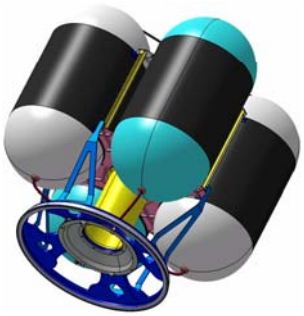


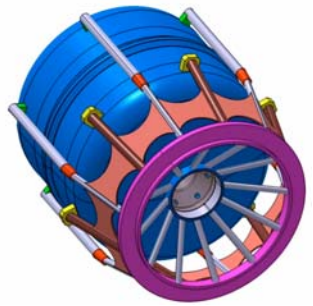
Optimal deployment



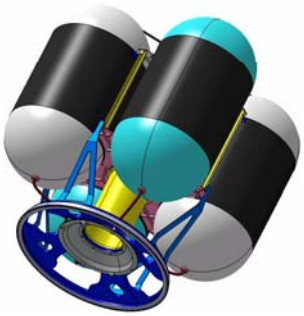
- **Start from GEO**
  - that can use best the existing satellite assets
  - has the larger market.
  - Most crouded
- **Use a phased deployment and opportunities as they come.**
  - **One opportunity is identified now !**



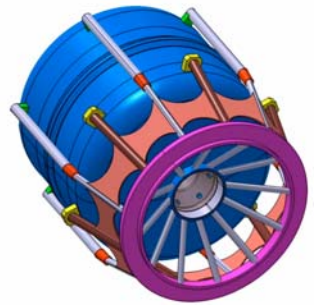
OOS kick-start Scenario



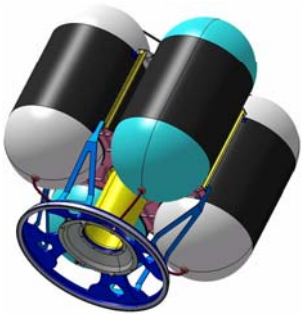
- One **tanker spacecraft** could be launched by the Ariane-5 ECA flight, to a high perigee GTO orbit.
- One **chaser spacecraft** (UA) could be launched within 3 years time to catch the tanker, revive it and use part of fuel to push it to GEO and the surplus fuel to perform missions (debris clean-up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



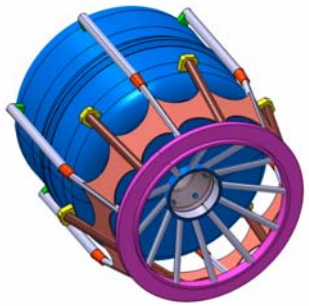
What is the tanker S/C (1)



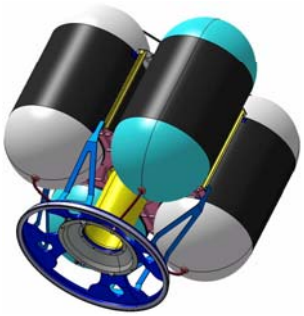
- Totally passive fuel storage system.
- Contains 3 t. storable propellants.
- Has “easy to catch” attitude behaviour.
- Has passive docking interface.
- Can be produced in 3-4 months.
- Can survive long time unattended.



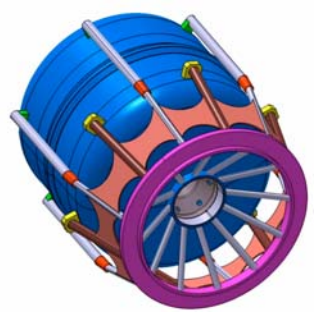
What its use could be?

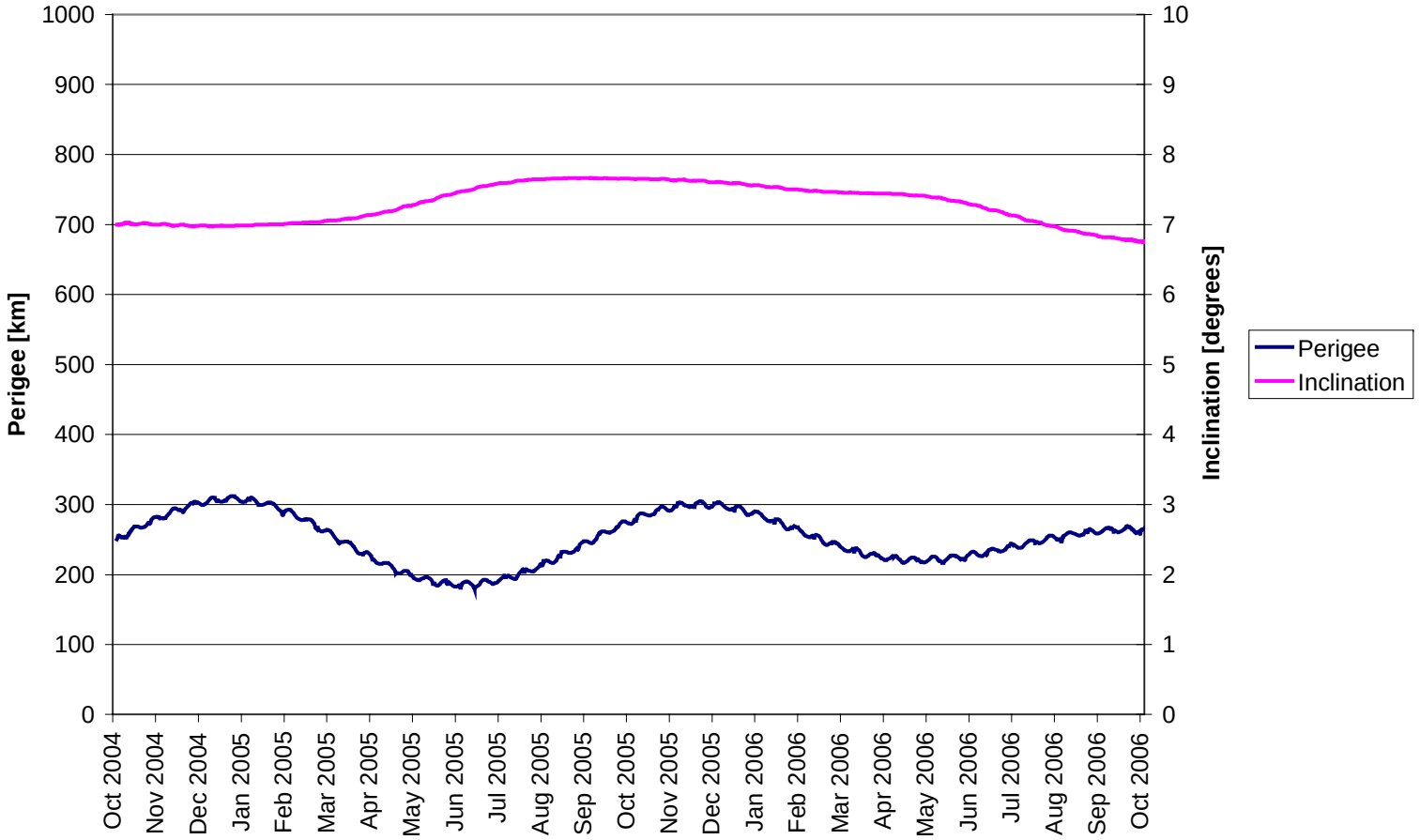


- To be the target of a chaser spacecraft that we call Utility Agent (**UA**).
- To demonstrate passive docking capability.
- To provide fuel to the **UA**. (fuel sufficient to reach GEO with 300 to 900 kg surplus for further service demonstrations).
- Is a primitive early substitute of the UB.

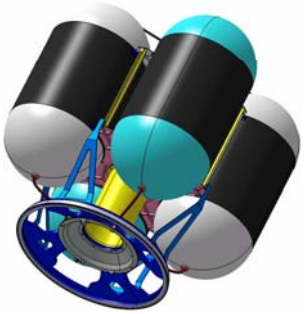


What orbit GTO ?

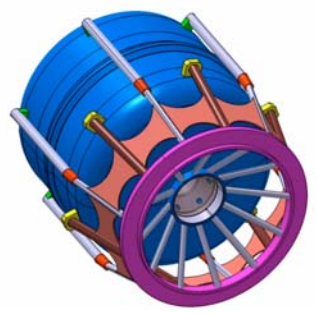




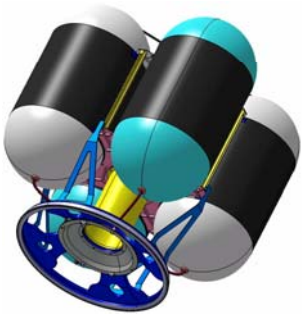
To : UN-COPUOS



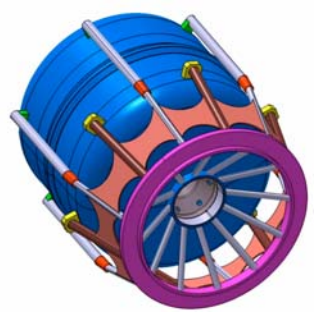
High perigee GTO characteristics

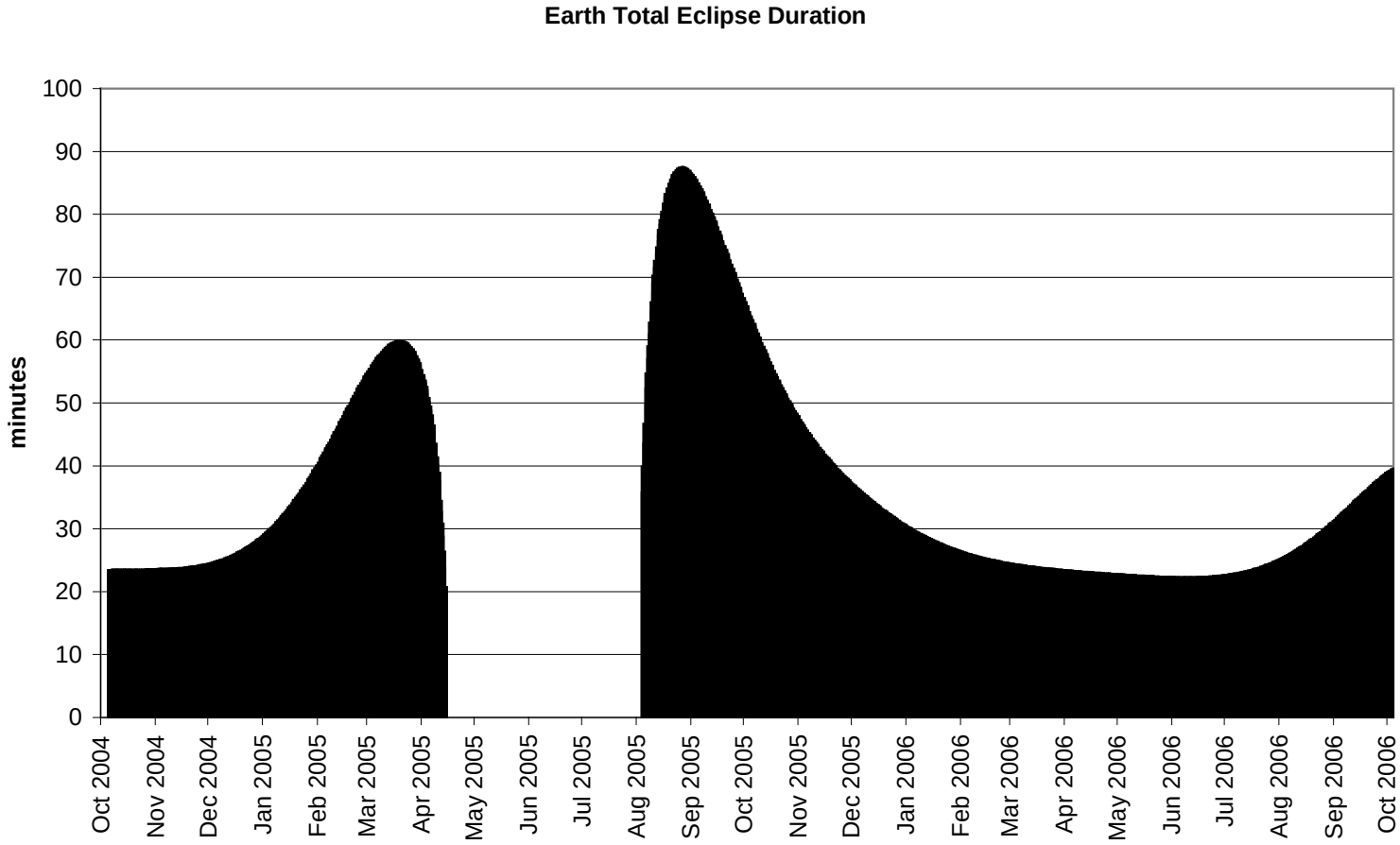


- Perigee height has periodic oscillation but within acceptable limits.
- Inclination evolution is in a narrow band.

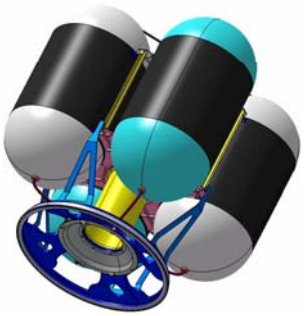


Why frozen ?

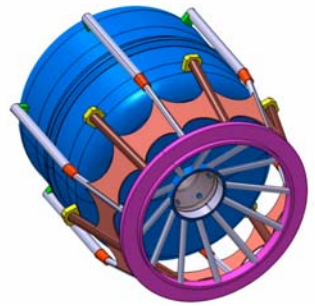




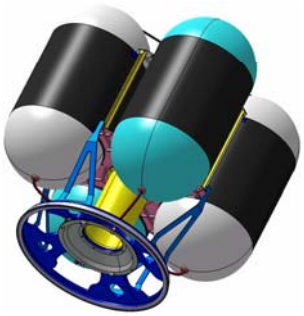
To : UN-COPUOS



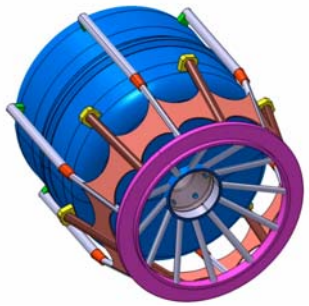
FAQ 1



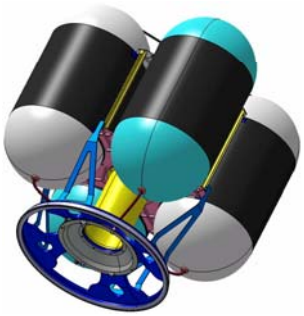
- **Isn’t it dangerous to Launch ?**
- Passive nature (no power to activate valves or heaters, no pyros, no EMC compatibility issue) ensures safety.
- No catalyst on board to enable ignition.



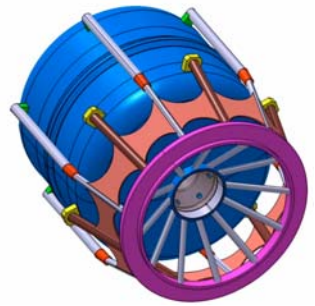
FAQ 2



- **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



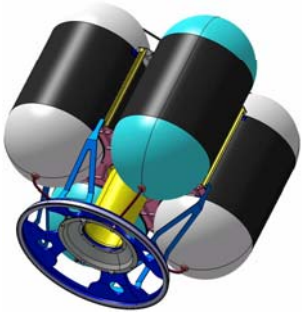
FAQ 3



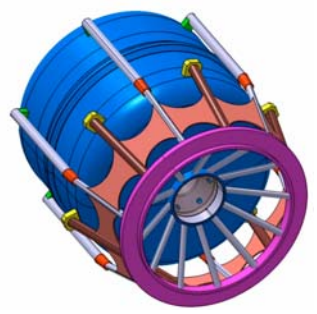
- **Is the tanker S/C feasible ?**

  Design available, team to realize available.
- **Is the Utility Agent feasible ?**

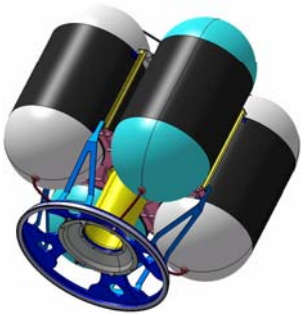
  Patent pending solution for final docking phase simplification (apparatus & method). Positive feedback from the patent office.



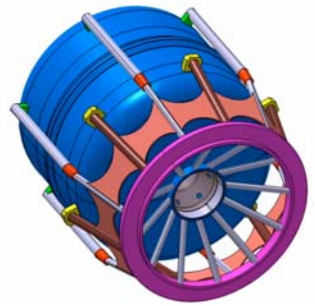
Why start now ?



- 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).

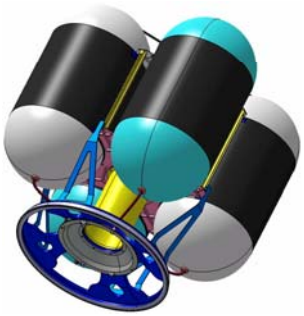


The benefit to GEO Ring USERS >...

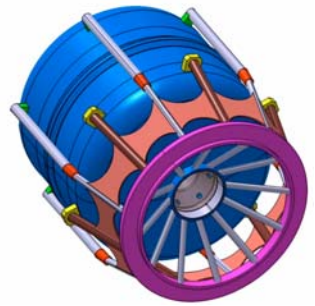


OOS will get finally a kick start date for performing:

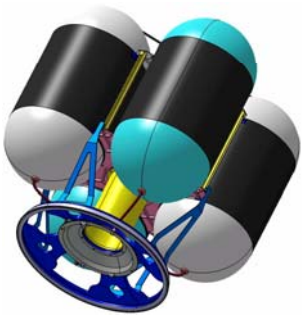
- **PHASE 0 (Demo)**
  - Inspection in-situ;
  - Transportation of spent Apogee Kick Motors and upper stages to grave yard;
  - Transportation of spent satellites to grave yard but also tidely (gathered);
  - Inclination correction (repetitive) extending lifetime;
  - Demonstrate / optimise refuelling process;
  - Cheap satellites will become readily available;



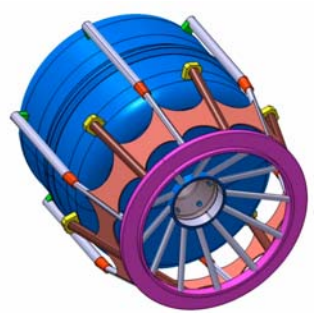
... Other benefits to GEO Ring USERS >...



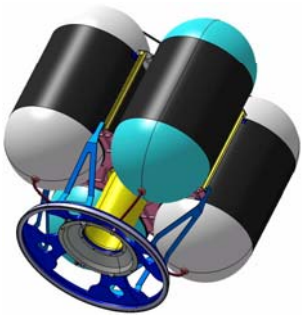
- **PHASE 1 (full deployment, at 360^0)**
  - Small refuelable satellites will emerge. Small entry cost to new entrants.
  - Refuelling of CS will be available only on the UB, or could be transported by UA given kinetic energy (Δv).
  - Bulk fuel quantities available on cargo basis for cheap refueling 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.



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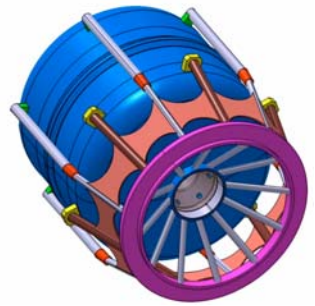
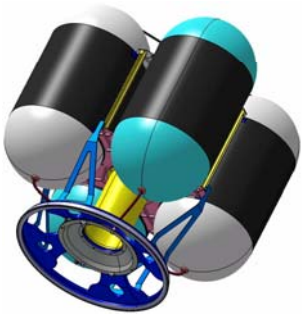
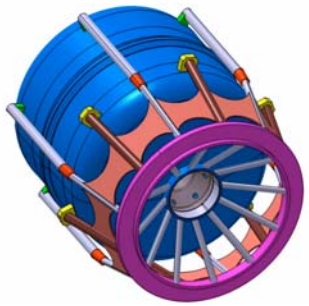


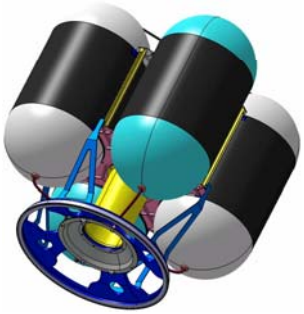
- **PHASE 3 (Maintenance demo & operations)**
  - Maintenance service will become available in situ for replacing modules, on the UB for deeper Unit Level interventions (momentum wheels, battery packs,…)
  - Progresive maintenace capability to lower levels in the enginnering higherarchy (subassembly level, Part level).



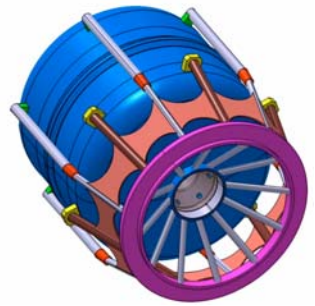
... Other benefits to GEO Ring USERS .



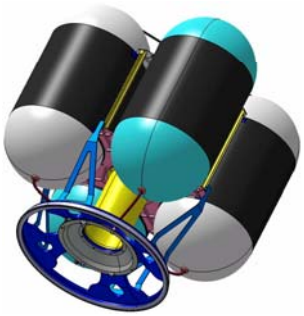
- **PHASE 4 (Assembly)**
  - Large long duration reusable structures like antenna reflectors will become available reducing the need to launch them with the spacecrafts.
  - Cost / performance ration will be reduced to record low levels.
  - Mass marker services will become available to low income customers globally (satellite mobile phones,) and moon bound & Lanrgange points projects will emerge.



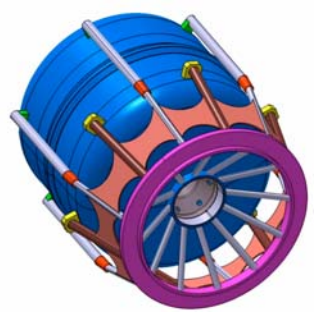
Status



- Continue to submit agressively 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

- mail questions to:

  TankerMission@GEO-Ring.biz

  OOS@GEO-Ring.biz