THE HERMES ON-ORBIT-SERVICING SYSTEM ARCHITECTURE FOR INSPECTION AND TRANSPORTATION SERVICES AT GEO

Charalampos S. KOSMAS

Kosmas GEO-ring Services, 3 Gruener Weg, 64283 Darmstadt, Germany, OOS@GEO-ring.biz

ABSTRACT

The HERMES OOS System Architecture answers to the question on how to provide OOS at the best commercial terms on GEO. It is based on applying symbiotic principles with its environment, ie the satellites to be serviced. It consists of 5 categories of reusable elements (spacecrafts or sub-spacecrafts) that complement each other. It can offer inspection services and transportation, the later to be offered in two distinct types. Fast transportation services will be offered for operational satellites, and slow transportation services for supplies and spent objects (AKM, S/Cs, upper stages).

Various scenarios for deployment are possible depending on commercial developments.

1. THE ELEMENTS

1.1 The Utility Base (UB)

The UB will provide initially essential services to the rest of the HERMES fleet (like refueling, pressure gas replenishment, battery charging, service channels) and in a stepwise manner will be enriched with more facilities that could include maintenance & assembly facility (robotic) and near space clean-up facilities (radar/laser) from small debris. Modular, mass from 2 t to 30 t over a 15 year deployment plan.

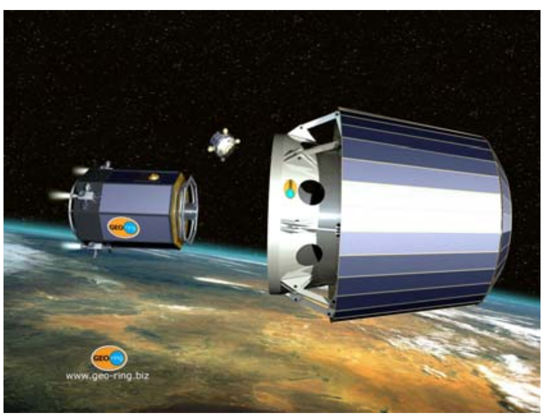

Figure 1. The Utility Base with a Utility Agent approaching and an Escort Agent facilitating the approach.

1.2 The Utility Agent (UA)

The UA, a small transportation vehicle, that will trade resources from the UB to the client satellites, will be refueled at the Utility Base between missions and will provide mainly transportation services to spacecrafts and objects. Two types of UA will be offered for the respective fast and slow transportation services. Two variants with mass 150 and 250 kg will cover a wide range of missions. It will have a docking port for the inspection satellite (Escort Agent), and a docking port for the Engine Module.

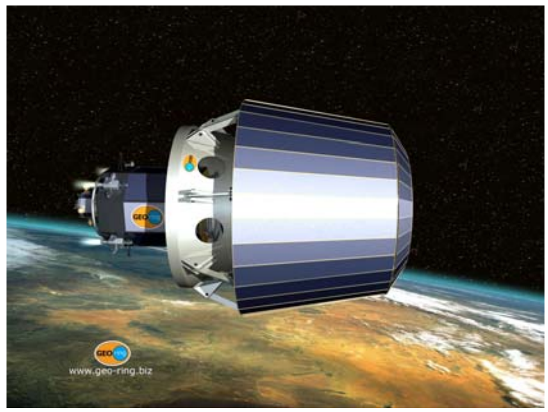

Figure 2. The Utility Agent repositions the Utility Base.

1.3 The Escort Agent (EA)

The EA is a deployable sub-satellite that would be carried in single configuration or pairs by the UAs for enabling visually the teleoperated docking operations and the inspection missions. Mass from 7 to 15 kg. Autonomy 10 h. It will use cold gas microthrusters that are totally harmless for the client satellite.

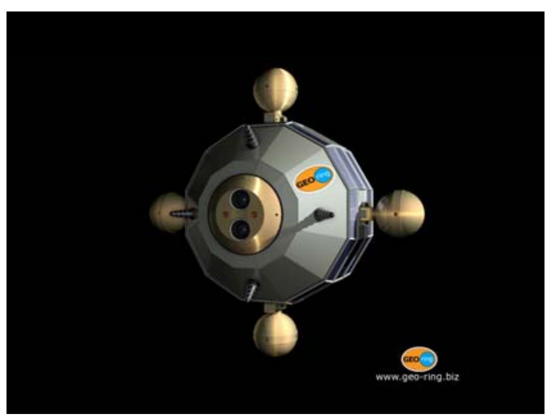

Figure 3. Escort Agent front view.

Proceedings of the Fourth European Conference on Space Debris, Darmstadt, Germany, 18-20 April 2005
(ESA SP-587, August 2005)

1.4 The Engine Module (EM)

The EM is a sub-satellite that will be ported by EA and attached to satellites that can still operate but are short of fuel, for offering to them routine station keeping. Mass 40 to 70 kg refuelable. Autonomy 3-5 years.

Figure 4. An Engine Module (EM)

1.5 The Orbit Raiser (OR)

The OR will be an ejectable (but reusable) boost stage, like Apogee Kick Motors (chemical/ cryogenic) that can bring satellites from LEO/GTO to GEO. It is designed so that can be auto-docked upon by a UA, before ejection, for towing. In the case the OR uses storable fuels it can act also as tanker. Provision of fuel in this manner facilitates deployment by reducing so the need for dedicated Utility Base from the beginning. It also assures availability of fuel in different longitudes.

2. THE SERVICES

2.1 Inspection

The Escort Agent will capture real time visual information, which will be forwarded to the ground through the Utility Agent and/or a third Satellite. The porting of the Escort Agent to the area of operation will be performed by the Utility Agent. The visual information can be used for many purposes. One will be to facilitate the docking, another to provide visual clues of anomalies, still another to provide infrared images of the client spacecraft or the Utility Agent, or the Utility Base.
These services will be needed during deployment and commissioning of a satellite, for anomaly resolution, for quality control based investigations and for resolution of insurance related disputes.

2.2 Transportation services

2.2.1 Fast Transportation

The Utility Agent will act as a generic transportation vehicle for transporting the EA in the area of an inspection target, if the mission is simply inspection, or it may transport the EM for attaching to a client spacecraft if the mission is to deliver an EM. Other major service will be inclination correction of satellites.

2.2.2 Major Inclination correction or re-orbiting

This service is of interest to many telecommunication satellites that have almost depleted their fuel and operate at a high inclination. Returning the satellite back to the operational window can boos the revenue by 30 million euro per year. However due to the expected drift after a while an additional element the EM need to be employed.

Figure 5. A UA carrying an EM is approaching a client satellite supervised by an EA.

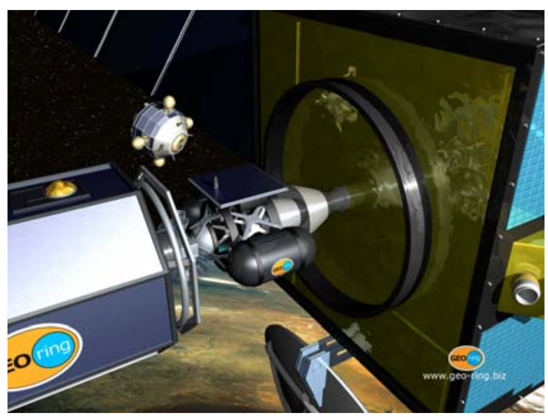

Figure 6. The fixing of the EM perimetricaly to the nozzle of the client satellite is checked by the EA.

2.2.2.1 Routine station keeping (orbit chances)

The routine station keeping of the client satellite both for East-West maneuvers and North South maneuvers will be performed by means of activating the EM (see Fig. 7).

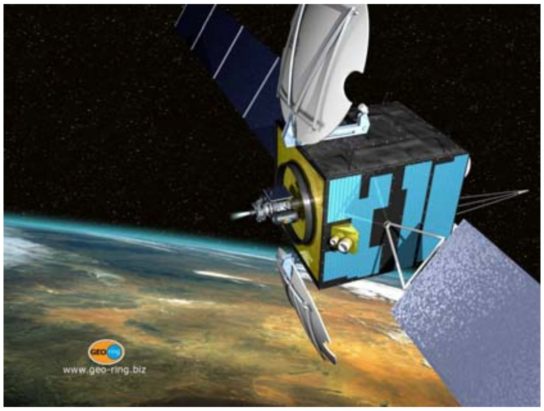

Figure 7. a client satellite is operating the EM that is attached to it.

2.2.2.2 Routine station keeping Attitude control

The nominal Engine Modules are not equipped with attitude control means for cost efficiency reasons and to avoid unnecessary duplication.
This maneuver can be performed more efficiently by the client satellite, assuming that the respective subsystem is functioning.
Even the attitude acquisition that is required in order to fire the Engine Module for orbit changing maneuvers will be performed by the client satellite as deemed more accurate and fast, based on a closed loop control.

2.2.3 Slow transportation – debris reduction

The slow transportation missions that will be performed by UAs equipped with ion propulsion thrusters will be provided for transportation of supplies and for re-orbiting satellites and other spent elements to the graveyard. From the debris reduction perspective this is the most relevant mission.

3. THE INNOVATIONS

Several recent innovations have enabled the creation of small footprint vehicles with versatile functionality. Some of them have been developed in house while some others have been developed in ITAR free economies.

3.1 In-house innovations

The patent DE10259638 of 09 Dec 2004 defines certain safe methods and equipment that enable the transmission of real-time video signal through the client satellite. This enables the use of the client satellite for the transmission of the signal during the docking or inspection missions, reducing so the mass and power requirements on the servicing elements (US & EA).
The same patent describes the use of the client satellite for the transmission of the telecommands towards the EM through the telecommand-telemetry stream of the client satellite. Some special commands or the “echo command” that have no functional use for the client satellite can convey the desired commands from the ground towards the EM without requiring additional frequency or large reception equipment.

3.2 Parallel developments

Certain technologies that have been developed in ITAR free economies have been identified as catalytic enabling factors for the deployment of the HERMES system. The most important are microthrusters that weight 60 grams per set of four. These microthrusters will be used for the propulsion of the EAs. Similarly for the illumination needs of the EA recent developments in high efficiency high illumination power blue LEDs enable the EAs to be small and operate under difficult natural light conditions.

4. COMPARISON WITH OTHER PROPOSALS

4.1 One off missions – no overheads

The HERMES system provides both fast transportation services, which are critical for the Operational satellites (based on chemical propulsion) and Slow transportation services (based on ion propulsion) for supplies and debris in order to offer attractive pricing.

Despite the mass budget considerations the chemical propulsion is by far superior to ion based propulsion for Inclination correction service due to the un-natural positioning of the external vehicle (UA / EM) with respect to N/S vector.
The inclination correction maneuver on a client satellite would last many hours and therefore it can not be completed in a single session.
It needs to be split between many nights for long periods. This induces the complication that the client satellite needs to change orientation each time, interrupting its nominal operation and the provision of service.
In comparison, a UA / EM based on chemical propulsion can perform the maneuver in one session in the course of a few minuets.

At the table below is given an example of services (Denis Wingo, 2004)) to be provided to a 4 tonne satellite by an Ion propulsion Tug of 1 tonne mass in comparison with the services to be provided by the HERMES elements ie an Engine Module of 75 kg and a Utility Agent of 150kg.
The comparison in Tab. 1 gives that for routine inclination correction services the HERMES system will need 12 seconds every 2 weeks and the other 2.45 hours every night.
For a major inclination correction of a satellite that had been drifting for 3 years the comparison in Tab 2) gives 4 hours of firing for HERMES and 112 days for the others. (See Tab 1.)

	Other on Ion	HERMES	Frequency of firing requirement
Mass of Satellite	4000 kg	4000 kg	
Mass of external DV provider	1000	75	
Total mass	5000	4075	
Firing time for Ion	2.45 hours		Per night
Firing time for 10 N		11.97 sec	every 2 weeks

Table 1. Comparison of routine NS maneuver duration.

3 year total for Ion	112 days
3 year total for Ion 4x10 N x 4225 kg	4 hours

Table 2. Comparison of duration of major NS maneuver

4.2 Smaller foot-print no apendances

In addition the choice of chemical propulsion for Inclination correction of client satellites enables the built up of service satellites with no protruding solar arrays which minimizes the risk and facilitates control.

4.3 Attitude control

No protruding elements means also that the UA can operate also as a spin stabilized.

5. THE STATUS

The project is at conceptual level. Identification of materials and partners is progressing.

A tanker spacecraft design is available for further dynamic analysis. This can be constructed on the basis of existing hardware in short notice to be used as payload in a qualification flight.

.

Figure 8. View of the structure of the tanker spacecraft.

6. REFERENCES

Dennis Ray Wingo, *2nd Responsive Space Conference*, AIAA, 19-22 April 2004.

The attached video file is an MPEG2 file.
It opens with Windows Media Player.

Either select the link above, or from the menu select "OPEN file" or press ctrl+O; browse to the directory that stores this file (\\posters\kosmas.m2v)
in the field "files or type" setect *.*
The file name "kosmas.m2v" should appear in the listing of the files in the directory you have selected to browse. If it does not appear then you have not selected the correct directory, try to locate it.

Enjoy the video.

The video is an artist's impression on the provision of inclination correction and delivery to a client satellite of an Engine Module.