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TECHNOLOGY IN-ORBIT DEMONSTRATION AND LOW-GRAVITY RESEARCH USING THE FREGAT UPPER STAGE AND THE KAP-CONCEPT – A PROPOSAL FOR A DEMONSTRATION MISSION IN 2010

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Abstract

Kayser-Threde GmbH has developed a concept called KAP (Kayser-Threde Auxiliary Payload Carrier) for In-Orbit Demonstration of new technologies and scientific experiments based on past experience with test satellites for Ariane 5. The main idea is to use available remaining payload capacity of the launcher to provide an efficient and flexible access to space for experiments and auxiliary payloads. The KAP Kit is fully autonomous providing the complete necessary infrastructure (power, data acquisition, telemetry) based on space qualified equipment flown on MAQSAT-B2 on Ariane L521 in 2005 and on TEXUS and MAXUS missions. Together with Lavoshkin Association a version to be accommodated onto SOYUZ/FREGAT called KAP@FREGAT has been designed and a successful (commercial and technical) feasibility analysis has been performed. The KAP Kit including the experiments mounted on an octagon raising cylinder underneath the primary passenger remains attached to the FREGAT upper stage. Using maximum battery lifetime the system can operate due to its autonomy up to one week in LEO. In addition the FREGAT Upper Stage provides specific performances like low-gravity environment/platform stabilization and/or pointing by the FREGAT ACS. Depending on the final experiment needs the mission profile will be designed finally to cope with the Customer's requirements. Typical potential customers of KAP are those looking for an in-orbit demonstration under real space environment (TRL 6 and higher), where a demonstrating on ground using representative test facilities is not sufficient to get a new technology qualified to be used in future space systems. On the other hand, scientific research using the low-gravity environment is another potential application for such kind of carrier. The combination of Kayser-Threde's KAP Kit and Lavoshkin's FREGAT capabilities leads to a flexible system for In-Orbit-Demonstration and scientific research as well as an access to space finally on a regular basis. Integrating new developed separation devices, KAP@FREGAT missions will serve also as an attractive CubeSat launching opportunity. The paper will present the current program and design status and describes the details of the envisaged first KAP@FREGAT mission in 2010 on SOYUZ/FREGAT.

1. KAYSER-THREDE BACKGROUND

Kayser-Threde has been working in space business for nearly 40 years in manifold areas. Due to its system integration heritage, Kayser-Threde is specialized in bringing scientific and technology experiments into space. This was demonstrated in several programs as presented hereafter.

1.1. MAQSAT – Maquette Satellite

Since 1997 Kayser-Threde is involved in Ariane 5 payload bay activities based on the development and manufacturing of a series of dummy and test satellites and structures, refer to [1] and [2].

The latest success was the MAQSAT-B2 mission, a test satellite for the Ariane 5 ECA L521 re-qualification in February 2005. It was equipped with a fully autonomous power and telemetry system providing servitude to the environmental monitoring system and additional onboard experiments (see Figure 1). These equipments can be considered as the back-bone of the autonomous KAP Kit.

Five experiments were selected for the MAQSAT-B2 mission: Sloshsat (tank fluid dynamics experiments satellite from ESTEC/Dutch Space), Boucle fluide (heat pipe experiment from EADS/CNES), DVCAM (Camera observation of separations from Dassault), CDVP (Vacuum pressure sensor – later cancelled), and QCM (Pollution sensor – later cancelled).

1.2. MFD – Multi-Purpose Fitting Dummy

In addition to the MAQSAT activities, Kayser-Threde has delivered several Multi-Purpose Fitting Dummies MFD-325 and MFD-500 to adjust the overall payload configuration of an Ariane 5 launch. These metallic raising cylinders of 325 mm and 500 mm height respectively were introduced underneath the primary passenger ACU as illustrated in Figure 2.

FIG. 1. MAQSAT-B2 on Ariane 5 L521

FIG. 2. MFD-325 configuration on Ariane 5 L517

1.3. OCAM – Online Camera System

Kayser-Threde developed a fully autonomous Online Camera System (OCAM), capable to monitor boosters, third stage and payload separation. The Online Camera System provides video sequences from up to four cameras via telemetry to ground. It supports acquisition and transmission of video data from two cameras in parallel. The picture information will be transmitted in real time in parallel to the monitoring data.

The first application for OCAM was to monitor Ariane 5 boosters and main stage separation in October 2006 using an external camera on Ariane L533. In addition, two cameras mounted on ASAP 5 monitored a deployment experiment of a large reflector from JAXA for a duration of 90 minutes.

Due to its full autonomy the camera system can be used also on other launchers for launch and separation monitoring. It is designed to withstand the Ariane 5 environment and therefore shall fulfill respective requirements of other launchers.

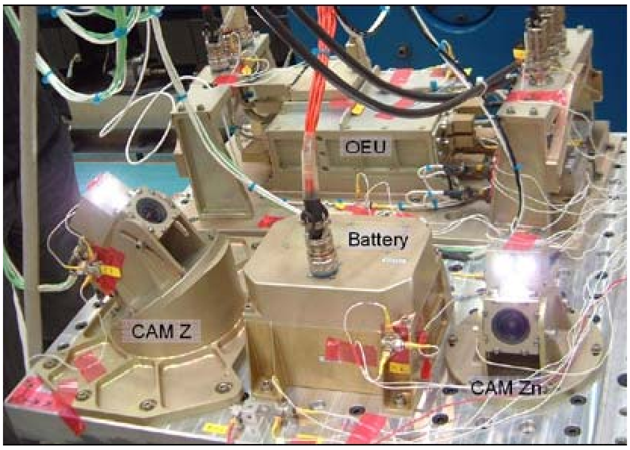

FIG. 3. OCAM test set-up for Ariane 5 L533

FIG. 4. OCAM picture from Ariane 5 L533 Lift-Off

2. LAVOSHKIN ASSOCIATION BACKGROUND

Lavoshkin Association was founded in 1937 and has been working in space business for nearly 50 years in manifold areas. Lavoshkin Association is specialized in the development of scientific and research unmanned spacecraft, as well as in the development of launcher related hardware. This is the case with the “L” Space Tug since 1965 (part of Molniya LV launched 279 times) and with the FREGAT Space Tug since the 1990s.

2.1. FST – FREGAT Space Tug

The FREGAT Space Tug (FST) was created by the Lavoshkin Association early 2000 under the request of the Federal Space Agency Roskosmos and the Ministry of Defence. The objectives of the FST are to increase significantly the payload capability, the injection accuracy, to enlarge the list of orbits compatible with current launch vehicles and to provide a higher reliability.

The first flight of the FREGAT Space Tug took place on February 9, 2000. To the present day, FREGAT flew 16 flights all of which were successful. An illustration of the FST and its performances are presented in Figure 5 and Table 1 respectively.

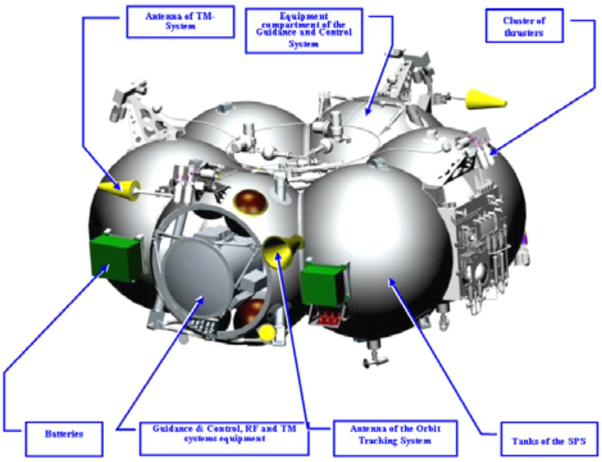

FIG. 5. FREGAT Space Tug

Features	Value
FST Mass [kg]	930
FST Height / Diameter	1.5 / 3.35 m
Main Propellant Mass [kg]	5250
Main Propellant Oxidizer / Fuel	NT / UDMH
ACS Propellant Mass [kg]	42
ACS Propellant	Hydrazine

TAB. 1. FREGAT Space Tug main characteristics

The FREGAT Space Tug (FST) provides solution to the following problems: transfer of one or several spacecraft from parking orbit into operational orbit or escape trajectory; in the case of multiple launches: the spacecraft placing into the operational orbits; the Upper Composite (UC = FST + S/C) transfer from the unclosed trajectory into the parking orbit ("additional boost" operation), this operation allows increasing of the injected payload mass; the UC stabilization in the course of the powered and cruising flights; generation and issuing of commands on the payload fairing jettison, the UC and S/C separations; provision of required attitude and, if necessary, the UC spin up during the vehicle cruising and prior to the spacecraft separation; by the use of the ground-based facilities: measurement of parameters of the intermediate orbits and orbits of the spacecraft injection; monitoring of status of the FST and if the spacecraft is injected in its final orbit the FST fly-away from the operational orbit of the injected spacecraft. At injection of some spacecrafts there is a margin of injected mass, which can be used for accommodation of additional payload, i.e. KAP.

2.2. PF – Payload Fairings

The development and manufacture of the payload fairings for launch vehicles represents a field in which Lavoshkin Association achieved great successes. The payload fairings developed by Lavoshkin Association are used on the following launch vehicles: Molniya, SOYUZ-FG, SOYUZ-2, Proton and Zenit.

FIG. 6. Payload fairing from Lavoshkin Association

FIG. 7. Payload fairing from Lavoshkin Association

All fairings have a metallic structure. In spite of the fact that fairings made of the up-to-date composite materials have lower mass compared to metallic ones, from a reliability and cost stand-point the Lavoshkin Association fairings are some of the best in the world. At present the Lavoshkin Association manufactures the fairings with the following diameters: 2,700, 3,715 and 4,100 mm.

3. KAP KIT GENERAL OVERVIEW

KAP (Kayser-Threde Auxiliary Payload carrier) shall serve as a future recurrent standard autonomous kit for In-Orbit-Demonstration (IOD) of new technologies and as test “exposure” facility for scientific experiments. KAP shall provide the complete necessary infrastructure (power, data acquisition and telemetry) to be fully autonomous from the launcher and compatible with various launchers.

Originally developed for an application on Ariane 5 [3] together with Arianespace the KAP Kit has been designed from the beginning to be flexible enough to be adopted also to other launchers like shown in this paper for SOYUZ/FREGAT.

3.1. General Mission Scenarios

Two different mission scenarios are available depending on specific mission needs: a Short Mission (SM) and a Medium Mission (MM). For KAP on Ariane 5 the main constraints are a GTO environment, no µg-phases and no separations. The accommodation of KAP on other launchers such as SOYUZ and Vega is also possible. In this case the mission takes place in a LEO environment and additional capabilities are provided, such as stabilized phases with low-gravity environment and possible separations (e.g. CubeSats). For both mission scenarios the experiments will be controlled by an onboard timer. All data transfer will be done via the Launcher Ground Stations network during lift-off (if required) and via Ground Stations after main passenger separation. Further features and services are also possible as an option such as telecommanding, but will increase the cost for a dedicated mission.

FIG. 8. MAQSAT-B2 Telemetry kit

The Short Mission (SM) is derived directly from the MAQSAT-B2 mission providing experiment monitoring during lift-off until upper stage passivation only. This mission scenario will typically be used for launcher technologies needing to be demonstrated during the launch phase. The data can either be downloaded during lift-off using the Launcher Ground Stations network or stored during lift-off and then downloaded after main passenger separation(s) via the selected European Ground Stations.

The Medium Mission (MM) is defined for a mission life time of nominal duration three days and maximum duration 7 days depending on the battery power needs which is the main design driver for the mission duration. Depending on the experimenters' requirements the monitoring and control during lift-off can be switched on or off. A combined SM-MM mission is also possible depending on the experimenter's requirements.

3.2. KAP Kit Accommodation

Different accommodations for the KAP Kit are foreseen in order to ease its integration onto the launcher and to have maximum flexibility for available flight opportunities. KAP can either be mounted on an additional load-carrying raising cylinder located underneath the launcher payload adaptor, or integrated on a platform for auxiliary payloads. Both configurations were designed focusing on minimizing interactions and constraints with the launch vehicle and benefits from the Kayser-Threde’s intensive experience as Principal System Integrator.

3.3. Electrical Architecture and Interfaces

The electrical architecture of the KAP Short Mission is identical to the one of the MAQSAT-B2 instrument platform qualified on Ariane 5 L521 in February 2005. The Short Mission (SM) is mainly of interest for experiments to be exposed to the launch vehicle environment.

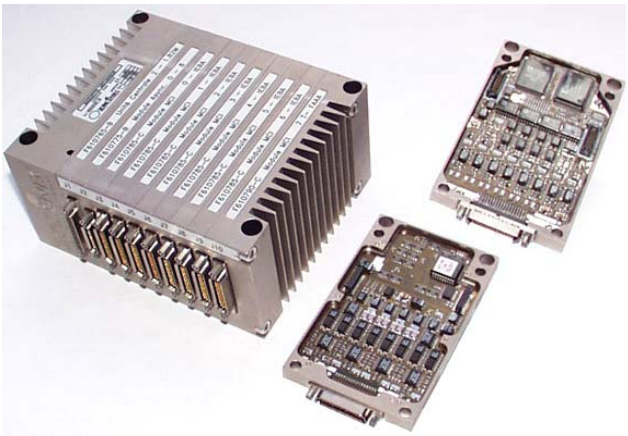

FIG. 9. CMA-2000 as key element of KAP-SM TMA

The MAQSAT-B2 program was a major step in development and successful flight qualification of the autonomous telemetry kit. The data acquired during the KAP Short Mission (SM) can either be transmitted directly on ground using the launcher RF system and ground station network (if needed) or stored and play-back when needed.

After passivation of the upper stage, direct down-link cannot be done any longer and, in case KAP shall collect experiments data longer than 3 hours, the data has to be transmitted to ground using a specific ground station contacted during specific time intervals. This means that the data has to be stored onboard and then played back only during dedicated time slots. In this case, the CMA-2000 will be upgraded with an onboard data storage and management capability.

For the KAP Medium Mission (MM) a more advanced onboard system will be used. For this mission scenario Kayser-Threde is benefiting from the experience from another experimental platform: the sounding rocket program TEXUS/MAXUS, providing 7 and 14 minutes of microgravity-environment respectively to onboard experiments. The responsibility of Kayser-Threde in that program is the provision of the servicing infrastructure for the experiments. Its flight qualified encoder system referred to as CTS-3000 is currently defined as the baseline for the KAP Medium Mission providing the upgraded necessary system functionalities [4].

The system is more powerful in terms of interfaces to the experiments. The CTS-3000 Encoder has a modular design which allows a centralized design (box with the master and slave in one housing similar to the CMA-2000 design) or a decentralized design, where each experiment or several experiments get one slave within the experiment electronics. This allows notably for harness reduction because of the concentration of the measurement data to one serial data stream.

The power for the Short and Medium Mission will be provided by a battery module(s) using Li-Ion batteries to limit the mass impact compared to Ni/Cd batteries as used on MAQSAT-B2. The MM mission duration is limited by the power system. It was estimated to have a 3 days nominal mission, but this can be extended depending on the final experiments' configuration up to 7 days. Payload mass can be substituted by additional battery modules and vice versa.

For the downlink, dedicated antennas will be used, which will be placed on the outside of the raising cylinder. If no monitoring, data acquisition or down-link during lift-off is required the Medium Mission has even less interaction with the launcher than the Short Mission which might need an antenna on the outside of the fairing or upper stage, if real time date is needed.

<table>
<tr><th>Electrical I/F</th><th>SM</th><th>MM</th><th>Remark</th></tr>
<tr><td rowspan="2">Power I/F</td><td colspan="2">28 V 25W average for experiments
(250 W peak manageable)</td><td>Li-Ion battery</td></tr>
<tr><td colspan="2">6 outlets
2 x PCDU (increment of 4)</td><td>Include current protection</td></tr>
<tr><td>Data I/F</td><td><u>CMA 2000</u>
2 serial async. lines (up to 6 possible, 1 x MilBus possible)
16 analog channels (with conditioning)
20 digital in
80 standard analog channels
1 serial synchr
Baseline 1 unit (2 units max)</td><td><u>CTS 3000</u>
6 serial async. lines with 1 master and 2 slaves (each slave increases by 2)
64 analog channels (with conditioning)
96 digital in / 72 digital out
8 analog channels out
1 serial synchr
Baseline 2 slaves (12 slaves max)</td><td>RS-422 (max rate 38.4 k Baud)
Data handling can be upgraded (more mass and power needed, reducing payload resources)</td></tr>
</table>

TAB. 2. KAP Baseline Electrical Surfaces

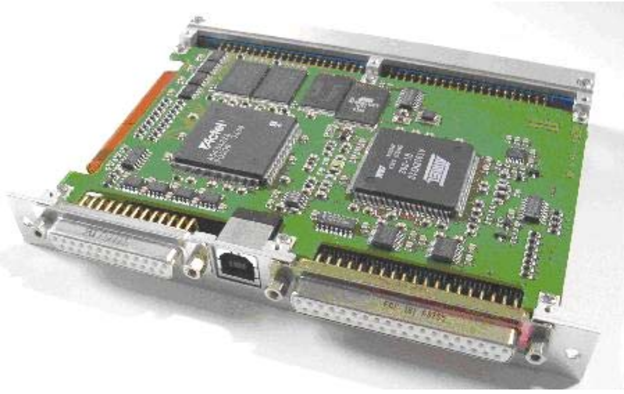

FIG. 10. CTS-3000 as key element of the KAP-M TMA

The Short and Medium Missions will be controlled autonomously by an onboard timer. Tele-commanding is not part of the baseline scenario (for cost-saving reasons), but can be added optionally on request enabling control of the experiments' operations from ground. The telemetry link is established via S-Band. Up to 8 GB of data can be downloaded to the dedicated ground station (onboard mass memory of 2 GB step card). The interfaces may be increased in terms of numbers (e.g. outlets, data lines etc.) taking into account that the overall resources such as power, mass storage, data processing and communication performance are limited to fixed values and have to be shared between the experiments.

Finally, the EGSE concept for the two mission scenarios was defined based on the experience and qualified hardware from previous and currently running Kayser-Threde missions and projects. The electrical interfaces preliminary defined and used as the baseline for customer survey and experiment adaptation are given in Table 2.

3.4. Micro-Satellite Separation

During the first KAP Customer Day in 2006 (see also chapter 5), it turned out that the optional integration of micro-satellite separation devices would provide KAP with a further interesting feature. Several deployment mechanisms of any type can be accommodated such as IBL and P-POD for micro- and pico-satellite class respectively. This configuration is referred to as KAP-CUBE.

4. KAP@FREGAT MISSIONS

4.1. Mission Overview

The KAP@FREGAT Missions are proposed to be carried out in the frame of the three Russian Meteor-M Missions. A precursor mission shall take place on the second Meteor-M Mission planned mid of 2010. KAP@FREGAT will use part of the remaining payload capacity of the Meteor-M Missions. The overall mass margin for these missions is approximately 1,000 kg.

The three Meteor-M spacecrafts will be injected with the following orbital parameters:

– Orbital period 101.307 min
– Semi-major axis 7,202.090 km,
– Inclination 98.786°
– Eccentricity 0.00112
– Argument of perigee 66.5°

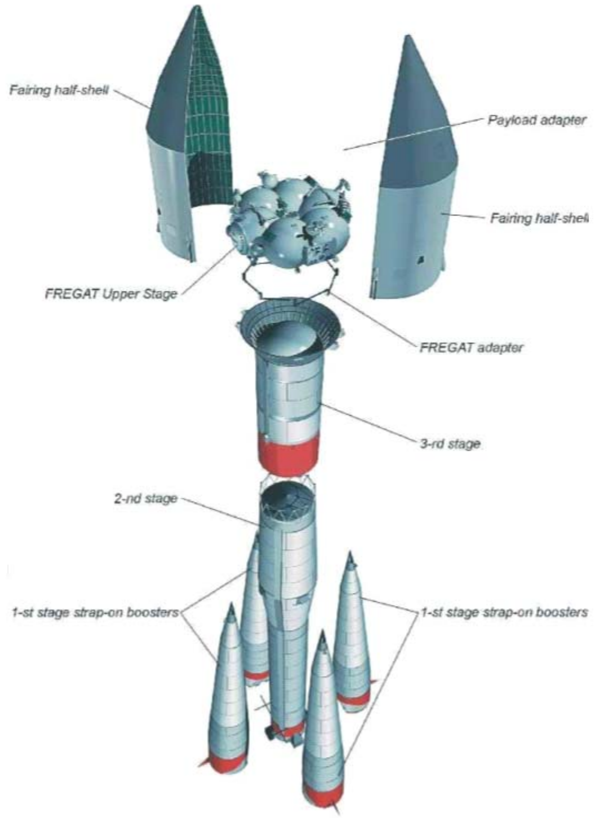

FIG. 11. SOYUZ-FREGAT Launch Vehicle

4.2. KAP@FREGAT Accommodation

The following figure illustrates KAP and its experimental payload ("green boxes") mounted on its adaptor structure on top of FREGAT.

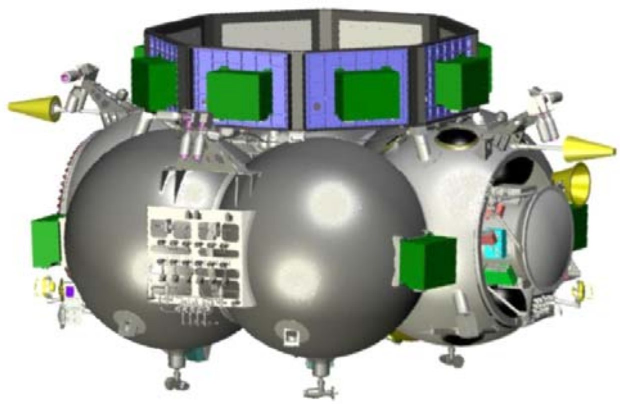

FIG. 12. KAP and adaptor structure on SOYUZ/FREGAT

The KAP@FREGAT accommodation follows finally the same logic as applied during the GIOVE-A mission: an "empty" load-carrying cylinder was introduced between the upper stage and the payload adaptor, refer to Figure 13.

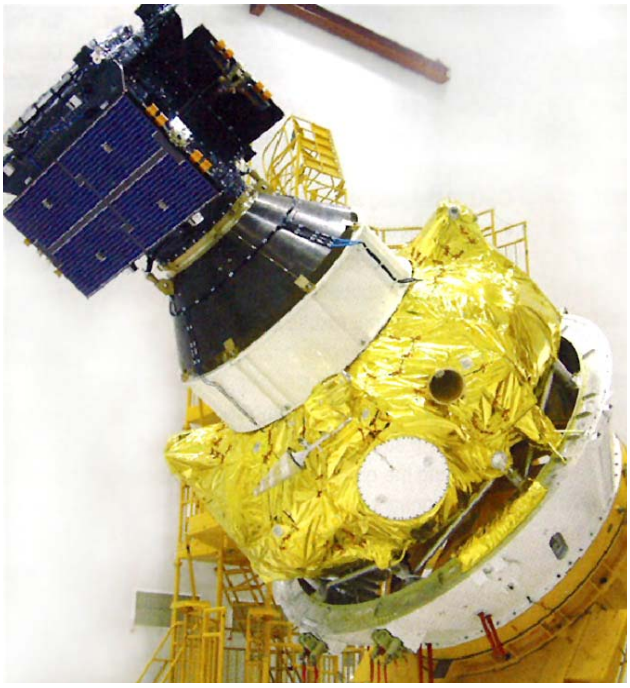

FIG. 13. GIOVE-A on SOYUZ/FREGAT

4.3. Adapter Structure

For this mission, the KAP Adapter structure is provided by Lavoshkin Association and consists of an octahedral prism of 500 mm height with 8 holes intended for a prism attachment to the FREGAT Space Tug at the lower interface and 8 holes in the upper interface intended for provision of attachment to the Meteor-M spacecrafts.

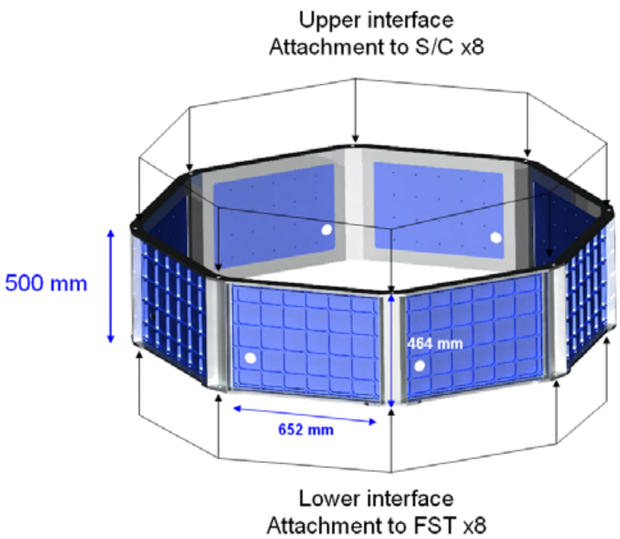

FIG. 14. Adapter structure for KAP on SOYUZ/FREGAT

The KAP Adapter structure is made of AM material. Its preliminary mass is estimated to approximately 100 kg. The KAP equipment and its experimental payload are bolted to the external lateral panels of the octahedron. Each panel is 464 x 652 mm² in size and includes a mounting interface of 384 x 572 mm². The equipment and payload can either be mounted inside or outside of the support structure, depending on customer requirements. 50 mm diameter holes are provided in the panel; they are intended for the mounting of the equipment from two sides of the Adapter (from the outside and inside).

Eight vertical beams made of AM alloy are arranged on the prism edges; they are welded between them at the upper and lower belts by the reinforcing elements in the common structure. The stiffness of the KAP Adapter structure was designed to cover up to FST maximal load-carrying capability.

4.4. Mission Profile

For the Meteor-M missions, Kayser-Threde has agreed with the respective launch authorities to have minimum interfaces with the mission plan and with the launcher and a maximum re-use of existing design and ground equipment to lower the risk and to have the necessary flexibility because of the existing schedule constraints. Nevertheless, it is planned to realize a maximum duration of 7 days to provide significant in-orbit mission time for the experimenter community. A study is currently under preparation regarding the possibility of introduction of new features such as possible stabilization of the upper stage providing low-gravity conditions during the complete mission.

After separation of the main passenger(s) approximately 32 minutes after lift-off, KAP remains on the launcher upper stage in LEO orbit with a moderate spin-rate motion around the launcher longitudinal axes. The attitude pointing at separation is defined by the launch authorities according to mission requirement. In the course of injection from lift off until separation of the Meteor-M spacecraft, all KAP equipments are deactivated (baseline), and the attitude conditions during this phase are defined by common requirements on attitude of the FREGAT and the Meteor-M spacecraft. Once the Meteor-M spacecraft is separated, all KAP equipments are activated and remain in this state until completion of the KAP@FREGAT mission. The FREGAT attitude control conditions are defined based on thermal mode provision and requirements. The requirements imposed on the upper composite and FREGAT attitudes are necessary to keep the structural elements, systems, units and equipment of the FREGAT and spacecraft in the desired temperature ranges during the course of all phases of their operation.

In order to meet the FREGAT requirements on provision of specific thermal modes, the FREGAT flight should be three-axis stabilized or stabilized by spin up. In order to provide the FREGAT required thermal mode at its stabilization by the spin up, the vehicle should rotate relative to $+OX_{FVST}$ axis with an angular velocity at least 1 deg/sec. The angle between the $+OX_{FVST}$ axis and direction to the Sun should be in a range of 0 to 110 degrees. In order to provide the FREGAT necessary thermal mode during coast flight phases in the case of three-axis stabilization control, an angle between a projection of a “FREGAT - Sun” Vector to the $X_{FVST}OZ_{FVST}$ plane and positive direction of the $+OX_{FVST}$ axis should be in the range of ±110 degrees. The angle of deviation of the “FREGAT - Sun” Vector from the $X_{FVST}OZ_{FVST}$ plane should not exceed 18 degrees in the direction of $+OY_{FVST}$ axis and it should not be restricted in the direction of $-OY_{FVST}$ axis – refer to Figure 15 and Figure 16.

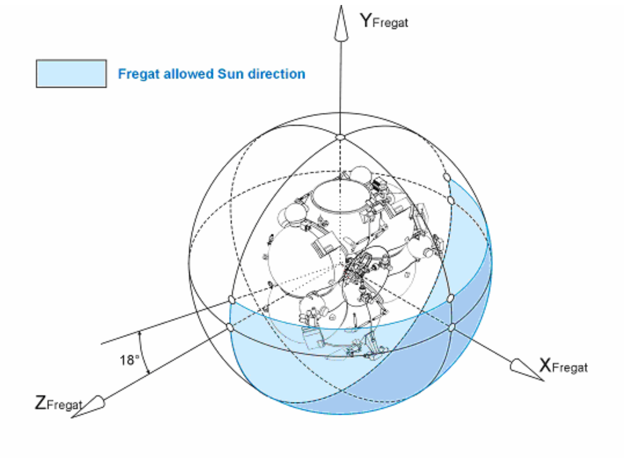

FIG. 15. Allowed Zone of the FREGAT Pointing to the Sun (three-axis-stabilized mode)

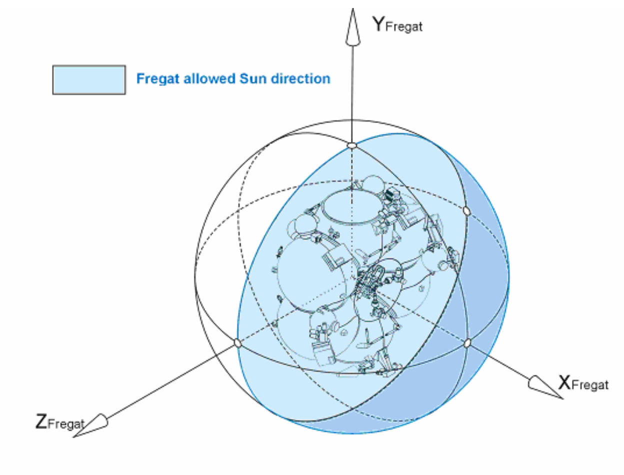

FIG. 16. Allowed Zone of the FREGAT Pointing to the Sun ("barbecue" mode - spin up attitude control)

These requirements imposed on the FREGAT attitude relative to the Sun do not concern the turns prior to fulfilment of powered flight parts and telecommunication contacts with a duration of not more than 20 min. With the provided attitude control the maximal areas of the FREGAT angular stabilization during cruise are ~20 to 25 degrees. This is defined by the limit angles of deviation of the FREGAT gyroscopic platform. The periods of operation of the ACS thrusters for the FREGAT stabilization during cruise at the stabilization zones ΔφX,Y,Z = ±20 deg for the FREGAT with nominal features after separation of the main passenger are correspondingly: TX = 400 sec, TY = 560 sec and TZ = 720 sec. The Initial Launching Coordinate Frame, relative to which the FREGAT angles of attitude axes are computed, materializes by the pre-launch adjustment of axes of the three-axis gyro stabilizer (TGS). A drift of the TGS axes defines by instability of the systematic components of "drift" of the gyro-s at launch from their mean value. According to the TGS Technical Specification, the drift value relative to the OX, OY, OZ axes is approximately 0.015 arc.sec/sec. During 24 hours the TGS drift relative to each of the OX, OY, OZ axes and can therefore reach 0.5 degree.

4.5. Payload Budget

Regarding the payload envelope, Table 3 presents the general figures depending on the selected flight configuration.

Payload mass will be homogenized around the structure in order to cope with physical measurement requirements. Payload capacity can be substituted by additional battery on demand.

Power budget will be tuned to optimize power availability depending on the selected experiments and mission scenarios. For each of the 8 panels, the maximal payload mass and volume are respectively 50 kg and 400 x 500 mm² by h = 500 mm.

Payload	**SM**	**MM**
Mass	250 kg	195 kg
Power	50 Ah	300 Ah
	25 W average – 250W peak @ 28V	

TAB. 3. Payload characteristics

5. POTENTIAL CUSTOMERS

As outlined before there are different concepts available for access-to-space of auxiliary payloads. Therefore, it is necessary to highlight the differences between the KAP concept and other solutions and to stress in further detail the concept logic. One of the main problems for auxiliary payloads in Europe is that there is no European-wide self-standing programme coordinating together both the different flight opportunities and the experimenters' needs. Such a programme is well established meanwhile in the United States and there is a clear need to have such a similar programme in Europe, preferably organized by ESA for any European experiment looking for a flight opportunity.

An initiative such as KAP is not straight forward to establish. In fact due to the lack of flight opportunities, many experimenters do not get budget approval to develop their experiment (i.e. technology demonstration or scientific payload) and wait for a last minute single-event flight opportunity to initiate the activity (refer to MAQSAT-B2 on L521 in 2005). ESA announcements of flight opportunities for such a single-event are often not successful due to the fact that advance planning is necessary in particular to raise budget. On the other hand, the announcement of opportunity for the German OOV-programme (On-Orbit Verification) for identifying payloads for the TET satellites was very successful and received more than 60 serious answers from German institutes and industry. The difference is simple: the announcement of opportunity was at that time embedded in a national space agency programme and TET will not be a single-event but a minimum of two satellites and even more in the event that it is a success.

THE KAP PAYLOAD

The KAP family shall provide In-Orbit-Demonstration for a wide range of technology and scientific experiments:

- Solar arrays
- Navigation equipment
- Gyros
- GPS, GALILEO equipment
- Electronics
- Electronic drift analyzer
- Lasers
- Thermal equipment
- Antennas
- Telemetry experiments
- Star sensors
- Video experiments
- Mechanisms
- Communication technology
- Propulsion technology
- Sloshing experiments
- Deployables
- Separation devices
- Plasma analyzer
- etc.

TAB. 4. Selection of typical KAP Payloads

In the meantime Kayser-Threde was awarded with the TET-1 Phase CD contract scheduled to be finalized mid 2010 with a launch as piggy-back also on SOYUZ/FREGAT. This would allow for a combined KAP/TET IOD mission using obvious synergies.

In April 2006 and November 2007 Kayser-Threde organized KAP Customer Days where institutes, industry and agencies gathered to discuss the concept and the needs of this sort of In-Orbit-Demonstration facility and recurrent programme. The discussion has shown, that there is a clear need Europe-wide for such a kind of program, but the concept has to be specified in more details to take into account the different customer needs. Therefore, KAP shall be understood as a flexible kit with a baseline concept and mission scenarios able to be expanded and adapted on the complete European launcher family providing a wide range of applications.

A dedicated Call for Interest for a KAP-DM (Demonstration Mission) and the KAP program was published in ESA EMITS News in September 2007. This Call of Interest includes all necessary information (User Manual, KAP Policy, etc.) about the KAP-DM and gives an outlook on the activity planning. This shall enable all experimenters to demonstrate their interest without any obligations. This Call of Interest remains open and is valid also for the precursor mission on SOYUZ/FREGAT (refer to [5]). Kayser-Threde will evaluate all proposals and contact all interesting experimenters to discuss the next steps. The Questionnaire for Experiment as a first step to enter into a KAP process is also available on-line [5].

Both KAP Customer Days were really successful events where more than 80 industrial and institutes were represented together with some of the most prestigious launch system providers such as Arianespace and Lavoshkin Association and last but not least ESA, DLR and CNES.

FIG. 17. Invitations to KAP Customer Days

6. PROGRAMMATIC ASPECTS

The main objective of the KAP programme is to provide recurrent flight opportunities for auxiliary payloads as piggy-back solutions on various launchers. There is a clear need for In-Orbit-Demonstration of future technologies to be used in space. A number of technology developments stopped at a certain TRL (Technology Readiness Level) with an on-ground verification programme, missing the chance for an access to space to finalize the development, especially when the requested representative space environment for qualification cannot be simulated on ground. Here, KAP shall serve as one possible solution for an In-Orbit Test Facility for technology demonstration on equipment and at subsystem level.

On the other hand KAP can also serve as “In-Orbit Exposure Facility” to be used by the scientific community for the defined short or medium mission scenarios. KAP@FREGAT offers various accommodation possibilities for experiments to be exposed to the space environment. It has been agreed with Lavoshkin Association to keep maximum flexibility w.r.t. the operational needs of the experiments. The high performance capabilities of FREGAT make especially this upper stage to the most interesting one comparing to others for a medium mission of KAP.

On the other hand KAP can also serve as In-Orbit Exposure Facility to be used by the scientific community for the defined short or medium mission scenarios. A database of both auxiliary payloads and flight opportunities has been generated in order to provide up-to-date information on current and future opportunities for potential customers. The mission and system requirements will be adapted based on the final mission scenario and primary passengers and the mission and design concept for the KAP demonstration mission will be frozen.

Kayser-Threde has collected manifold experience as experiment system integrator and partner of the science programme both in manned and unmanned activities. Based on that, Kayser-Threde's role in that programme is to pursue its system integrator role and, in addition, to act as a flight opportunity broker being the single interface between the auxiliary payloads and the launcher authority. The payload life cycle will cover:

- Experiment's selection for flight opportunity with KAP
- Experiments industrialization and verification
- Experiments acceptance
- Integration activities with KAP
- System test including final verification steps
- Transport and storage activities
- Launch preparation activities
- Launch campaign
- Mission operations

With the KAP programme, Kayser-Threde will provide a full services package to the customers including:

- Support to experiments to achieve on time flight readiness
- Integration of experiments
- Integration of KAP and experiments on the launcher
- Organization and completion of the launch campaign
- Mission operations and data transferred to ground
- Deliver experiment's data and environmental measurement data to the experimenters.

With a successful demonstration mission in 2010, the logic of the KAP programme will be of such a kind that it will allow for a 1-year sequence between each KAP mission on altering launchers. A concept proposal for KAP to be used on the future small European launcher has already been presented [6].

The full industrialization phase of KAPn is expected to last one year from KAPn programme kick-off to acceptance and shipping to the launch site providing a full set of KAP payload is available and all experiments for that mission are ready for integration in due time.

There is a logical flow defined for the development and industrialization of KAPn from Programme kick-off to the final in-orbit mission. After a certain acquisition phase which can include a dedicated Call of Interest and will always include a specific KAP Customer Day, the experimenters are invited to place a request for flight on KAP to Kayser-Threde. Having a minimum number of experiments available, a Programme Kick-Off starts the delta-development and industrialization phase of a KAP mission.

According to Kayser-Threde experience, it is necessary in some cases to start the industrialization of a flight experiment well in advance before starting the dedicated KAPn program. But having a reliable and recurrent programme available such as KAP, the experimenters can plan for their flight opportunity on a much more reliable basis than in the past with single and suddenly occurring flight opportunities. Due to standardized interfaces, the KAP program shall provide a high flexibility allowing possible late exchange of payloads in case of late procurement. Kayser-Threde is available to support potential customers whenever needed to get on KAP and to select the right flight opportunity depending on their specific needs.

7. SUMMARY

KAP is a fully autonomous kit providing the complete necessary infrastructure (power, data acquisition and telemetry) to minimize constraints and interactions with the launch vehicle, increasing significantly the possibility for recurrent flight opportunities.

KAP@FREGAT is a specific mission designed for a flight opportunity on SOYUZ/FREGAT using the wide-range performance capabilities of FREGAT upper stage after main passenger separation for an IOD-mission of up to seven days. Together with Lavoshkin Association a feasibility study has been performed and successfully finalized having a complete mission and system design available.

A demonstration mission of KAP@FREGAT is scheduled for mid 2010. A Call for Interest published on the ESA EMITS News and on the KAP website, refer to [5], was issued already in September 2007 in order to identify and select first launching customers. Experimenters are invited to contact the Kayser-Threde KAP-team any time in case of interest in a flight opportunity. KAP, being compatible with various launchers, shall provide a wide range of possibilities. This shall diversify possible orbits trajectory, provide additional opportunity for low-gravity phases and secure finally a recurrent programme with at least one flight opportunity per year on alternating launchers.

8. ACKNOWLEDGEMENT

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