

# In-Orbit-Demonstration of New Space Technologies

## A Flight Opportunity with KAP

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### ABSTRACT

The success of Kayser-Threde's test satellite MAQSAT-B2 on Ariane L521 in February 2005 (2<sup>nd</sup> Ariane 5 ECA qualification flight) and its instrument platform equipped with experiments, sensors and an autonomous telemetry system has led to the development of a new autonomous experiment platform called KAP. KAP stands for Kayser-Threde Arianespace Platform and is a direct spin-off product out of Kayser-Threde's Ariane 5 post projects and experience. The main idea is to use the available remaining payload capacity of the launcher to provide a flexible and low-cost test facility for scientific experiments and In-Orbit Demonstration of new technologies remaining attached to the launcher upper stage. 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 regular flight opportunities. Two different mission scenarios are foreseen. One with KAP only being working during the launcher mission itself (called short mission), the other as medium mission to be switched on after upper stage passivation for up to 7 days in orbit. Different accommodations for KAP are foreseen in order to ease its integration. KAP can either be mounted on an additional load carrying raising cylinder located underneath the launcher payload adaptor (MFD type), or integrated on a platform for auxiliary payloads (ASAP-5 type). The technical concept for both mechanical and electrical subsystems for space segment and ground support equipment is mainly based on existing and space qualified technologies from the successful MAQSAT-B2 project and Kayser-Threde's sounding rocket programme TEXUS/MAXUS. In particular the data acquisition and telemetry unit as back bone of the KAP experimental payload infrastructure is a direct adaptation from these programmes to the specific mission needs. Finally, also the downlink scenario and ground segment is specified for a complete mission scenario.

In January 2007 KAP entered a Phase B with a co-funding from ESA in the frame of the GSTP-4 programme. A demonstration mission on Ariane ASAP-5 is scheduled in August 2008. A Call for Interest published in EMITS will be issued in the 2<sup>nd</sup> quarter of 2007 in order to identify and select first launching customers. KAP on VEGA and SOYUZ is the next step to adapt the concept to other members of the European Launchers' Family and provide additional performances. 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 altering launchers.

The present paper summarizes the latest status of the KAP development, including system design and mission scenarios, and provides information regarding the first demonstration mission and future possible applications.

## **KAYSER-THREDE'S ARIANE 5 EXPERIENCE**

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 programmes as presented hereafter.

### **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 ([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 systems providing servitude to the environmental monitoring system (and additional onboard experiments). These equipments can be considered as the back bone of the autonomous KAP Kit.

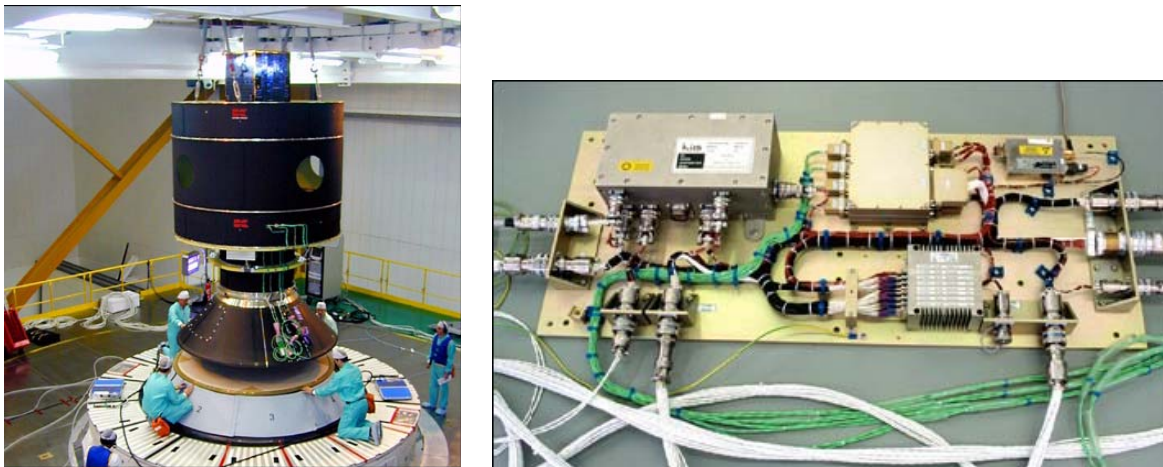


Figure 1: MAQSAT-B2 and its Telemetry Kit

### **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 were introduced underneath the primary passenger ACU as shown in the following figure.

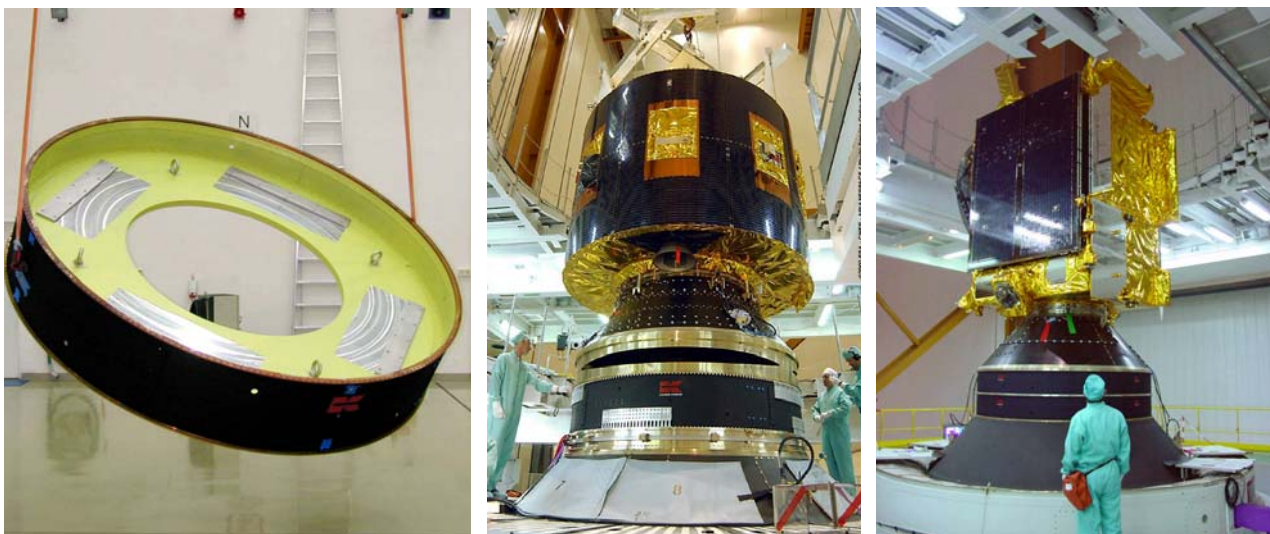


Figure 2: MFD-500 (left), MFD-500 on Ariane 5 L513 (center) and 2 MFD-325 on Ariane L517 (right)

## **OCAM – Online Camera System**

In addition, 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 4 cameras via telemetry to ground. It supports acquisition and transmission of video data from 2 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 during 90 minutes.



Figure 3: OCAM test set-up (left), pictures from Ariane 5 L533 Lift-Off (center) and booster separation (right)

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 fulfil respective requirements of other launchers. For more details please refer to [3].

## **KAP OVERVIEW**

KAP (Kayser-Threde Arianespace Platform) shall serve as future recurrent standard autonomous kit for the European launchers family 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. These features significantly ease the integration of KAP, minimizing constraints and interactions with the launch vehicle, and therefore should provide regular flight opportunities. From the programme point of view a first mission is planned on Ariane 5 in 2008 having after that successful demonstration mission respective flight opportunities every year also on other members of the European launcher family (planned on SOYUZ in 2009 and on VEGA in 2010).

### **General Mission Scenario**

Two different mission scenarios are available for KAP remaining in any case attached to the upper stage. Main constraint for KAP on Ariane 5 is a GTO, no  $\mu$ g-phases and no separations. However, the accommodation of KAP on other European launchers is possible depending on the mission profile leading to a mission in LEO and providing additional capabilities such as stabilized phases with low-gravity environment and possible separations (e.g. of CubeSats). The mission and the experiments will be controlled by an onboard timer. All data transfer will be done via the Launcher Ground Stations network during lift-off and via European ground stations after upper stage passivation. The major performance data for the KAP missions are presented in table 1.

The *short mission* 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 launcher mission.

The *medium mission* is defined for a mission life time of nominal three days and maximum 7 days depending on the battery power needs which is the main driver for the mission duration. Depending on the experimenters' need the monitoring and control during lift-off can be switched on or off.

Name	Duration	Major characteristics
KAP-SM	3 hours (short mission)	Online data transfer with up to 500 MByte of downlink data to Ariane 5 ground station network, power via batteries, 25W average payload power (50W peak power)
KAP-MM	3 days *) (medium mission)	Data storage and data transfer during playback with up to 500 MByte of downlink data per orbit during perigee swing by (orbit duration 10,5 h), power via batteries, 25W average payload power (50W peak power)

\*) 3 days mission is the nominal duration. The system is designed for maximum 7 days duration (see demo mission).

Table 1: KAP baseline missions duration

The described constraints shall ensure a cost-efficient solution for a KAP flight opportunity using available remaining launcher payload capacities. Further performance increase of KAP like telecommanding is technically feasible but will increase the cost for a dedicated mission.

### KAP Accommodation

Different accommodations for KAP 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 (MFD-type, see again Figure 2) located underneath the launcher payload adaptor, or integrated on a platform for auxiliary payloads (ASAP5-type).

#### Raising cylinder configuration

From structural point of view the raising cylinder configuration serves as a metallic structure having dedicated properties and characteristics similar to the flight proven MFD concept. The structure is constituted by an external cylindrical shell, an internal platform supported by a conical shell and two aluminium flanges interfacing to the adjacent upper and lower structure. Another concept consists in a light-weight structure configuration where the payload and equipment can be mounted directly on the inside or outside wall of the raising cylinder. An overview of these two KAP configurations is given in Figure 4.

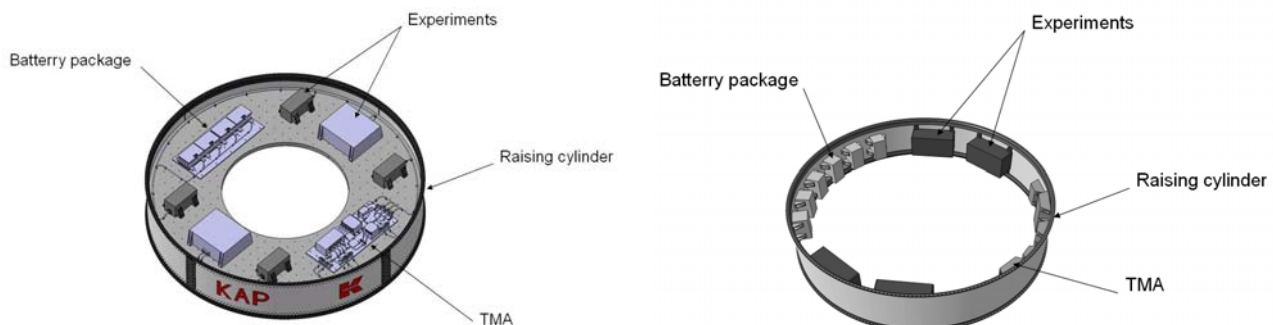


Figure 4: Raising cylinder configuration with KAP Kit mounted on internal platform (left) and mounted on cylinder wall (right)

Several accommodations are feasible: with or without SYLDA or SPELTRA, with a long or a short fairing. The following figure (left side) shows possible KAP accommodations on Ariane 5.

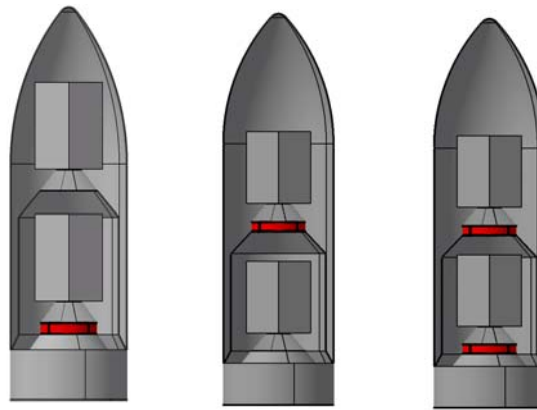


Figure 5: Possible Ariane 5 accommodation scenarios of the Raising cylinder configuration (left) and KAP family concept (right)

In addition to that, the raising cylinder serves as a trimming structure and shock damper to the overall launch configuration. This combination of auxiliary payload accommodation and improvement of primary passenger accommodation and launch environment is an optimum starting point to consider KAP as a possible flexible and recurrent payload bay structure simply to be added to the overall launch configuration for a KAP flight opportunity. Furthermore, first assessments have confirmed that it can be expected to have no negative effects on the QSL on the primary passengers when introducing a 500 mm raising cylinder underneath them.

To facilitate the recurrent KAP accommodation for Arianespace, each cylinder will be designed, manufactured and trimmed in such a way, that it has always identical mechanical characteristics allowing the launcher authority to simply add a model of KAP with each time the same static and dynamic characteristic to the CLA to be performed for each launch.

#### Platform for auxiliary payloads configuration

The KAP Kit can also be mounted on any platform for auxiliary payloads providing additional flexibility. This scenario is planned for the demonstration mission presented later on with KAP mounted on ASAP-5. Such kind of auxiliary payload platforms are used or planned to be used also on other launchers having in most cases empty “seats” available potentially to be used by KAP.

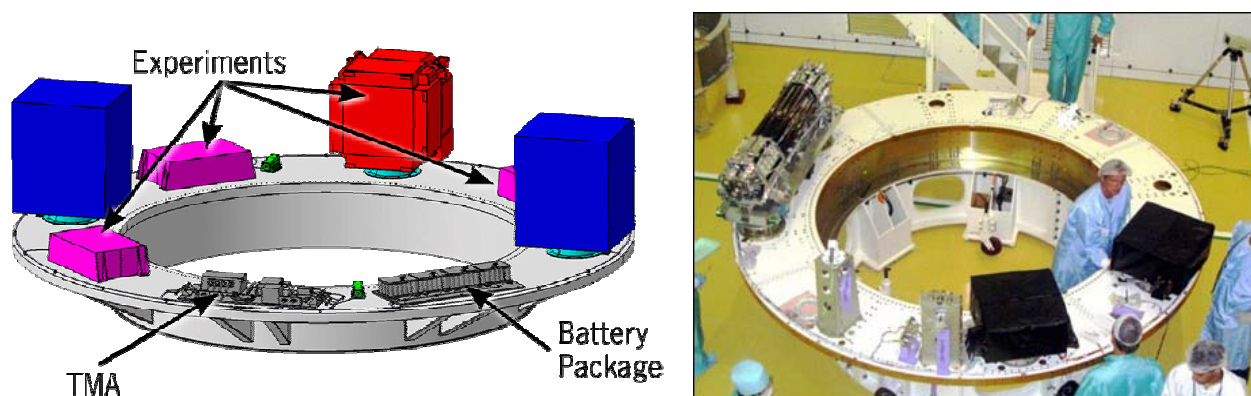


Figure 6: Platform for auxiliary payloads configuration (left, potential configuration of demo mission) and ASAP-5 of L533 (right)

#### Data Downlink Concept

To maximize the amount of data to transmit to ground during a GTO KAP mission the most efficient scenario is to use the short sequence of around 15 minutes at very low altitudes (250 to 800 km) once per orbit with high data rates of up to 5 Mbps by contacting the equatorial Ariane 5 ground station network (with Kourou as main station).

## 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 of the KAP concept to other solutions and to stress the concept logic again. One of the biggest problems for small payloads in Europe is that there is no European-wide self-standing programme bringing together both, the different flight opportunities and the experimenter's 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 kind of European flight experiment looking for a flight opportunity.

An initiative such as KAP is not easy to establish. In fact due to the lack of flight opportunities, a lot of experimenters have no interests to develop such an experiment to have it available in case of a single flight opportunity suddenly occurs with usually very tight programmatic schedules (like the MAQSAT-B2 on L521 in 2005). Announcements of flight opportunities for such single events are often not successful due to the same reason.

However, the AO for the German OOV-programme for identifying payloads for the TET satellites was very successful receiving more than 60 answers from German institutes and industry. The difference is easy to identify: The AO is embedded in a national space agency programme and TET will not be a single event but finally a regular programme in case of customer's needs.

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.

Figure 7: Overview on potential KAP customer (left) and invitation to 1st KAP Customer Day in 2006 (right)

In April 2006 Kayser-Threde organized a first KAP Customer Day where institutes, industry and agencies gathered to discuss the concept and the needs of such a kind of In-Orbit-Demonstration facility and regular flight programme. The discussion has shown, that there is a clear need Europe-wide for such a kind of programme, 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 scenario able to be expanded and adapted on the complete European launcher family providing a wide range of applications.

## KAP DETAILS

The following chapter describes the techniques, interfaces and boundary conditions in more detail to give a closer view on the single design solutions and adaptations made from other Kayser-Threde programmes.

### Electrical Architecture & Interfaces

The electrical architecture of the KAP Short Mission is identical to the one of the MAQSAT-B2 instrument platform qualified on Ariane L521. The short mission is mainly of interest for experiments to be exposed to the launcher environment only. The MAQSAT-B2 programme was a major step in development and successful verification of the autonomous telemetry kit because it could be demonstrated, that such kind of subsystem based on the CMA 2000 is fully compatible with the launcher. The data being acquired during the KAP Short Mission will be transmitted down simultaneously using the Ariane 5 RF system and Arianespace ground station network.

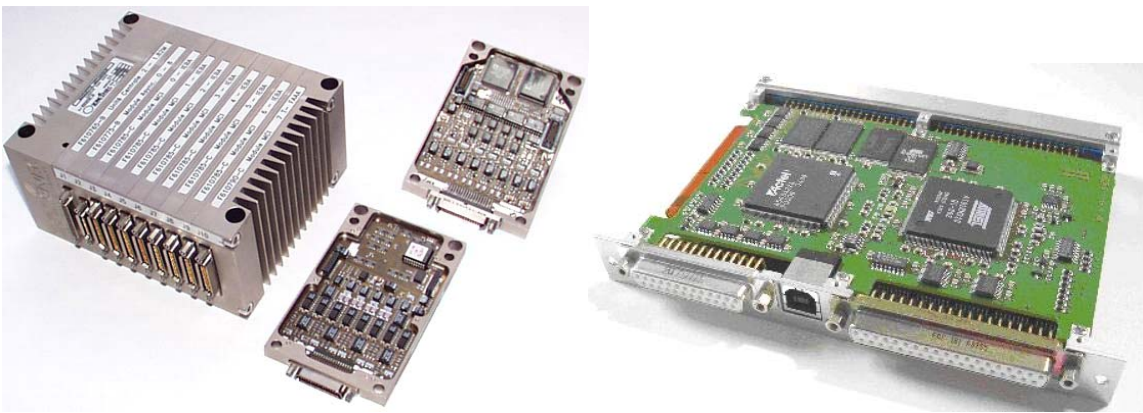


Figure 8: CMA 2000 as key element of the KAP-SM TMA (left) and Slave Module of the CTS 3000 TEXUS/MAXUS (right)

After passivation of the upper stage, this 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 a specific timeline per day. This means, the data has to be stored on board and sent down only during dedicated time slots. That for the CMA 2000 needs to be upgraded with an onboard data storage and management capability.

For the Medium Mission there is a more advanced onboard system planned to be used. Here, Kayser-Threde has adapted the experience from another experimental platform: the sounding rocket programme TEXUS/MAXUS providing 7 and 14 minutes of  $\mu\text{g}$ -environment respectively to the experiments on board. Kayser-Threde's responsibility in that programme is the provision of the necessary infrastructure to the experiments. Its qualified encoder system called CTS 3000 is currently defined as baseline for the KAP Medium Mission providing now the necessary functionality.

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 together in one housing similar to the CMA 2000 design) or a decentralized design, where each experiment or several experiments gets one slave within the experiment electronic. This allows for reducing the harness because of the concentration of the measurement data to one serial data stream.

The power for the Medium Mission will be provided by a battery package using Li-Ion batteries to limit the mass impact instead of using NiCd batteries for KAP-SM. Finally, the MM mission duration is limited by the power system. It has been estimated to have a three days nominal mission,

but this can be flexible depending on the final experiments configuration and extended up to 7 days. For the downlink 2 own antennas will be used, which will be placed in such a way, that a permanent contact to the ground station is ensured during data transmission. If no monitoring, data acquisition and downlink during lift-off is required the Medium Mission has even less interaction with the launcher than the Short Mission which needs an antenna on the outside of the fairing or VEB leading to a small constraint on the launch vehicle configuration. The Short and Medium Mission 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 to control the experiments' operation from ground.

Finally, the EGSE concept for the two mission scenarios has been defined based on the existing experience and space qualified hardware from previous and currently running missions and projects. The electrical interfaces preliminary defined and serving as baseline for customer survey and experiment adaptation are given in table 2.

Interface	SM	MM
Power I/F	28V 100W const. 6 outlets, 2 x PCDU (increments of 4)	28V 25W average 6 outlets, 2 x PCDU (increments of 4)
Data I/F	2 serial async. lines (up to 6 possible) (- 1 x MilBus possible) (CMA 2000) - 16 anal. ch. with conditioning - 30 standard analogue channels - 20 digital in - 1 serial synchr. Baseline one unit. (2 units max.)	6 serial async. Lines with 1 master & 2 slaves (for each slave add 2 lines) (CTS3000) - 64 anal. channels - 96 digital in - 72 dig.out (relay/TTL comm.) - 8 analogue out - 1 serial synchr. Baseline two slaves (12 Slaves Max.)
Timer / computer	None	Timer, time line controlled by programming
TC	None	None
Telemetry	500Kbit/sec S-Band link, switch to 100Kbit/sec (Kourou)	15Kbit/sec S-Band link 411MBit/per day(GSOC)
Memory	None	32Mbyte per slave
Heater I/F	32 Watt	
EGSE I/F	Via LAPTOP for each Exp. Ethernet for Data, 28V power	Via LAPTOP for each Exp. Ethernet for Data, 28V power

Table 2: KAP baseline electrical interfaces

### Optional Pico-Satellite Separation

During the KAP promoting tour and especially on the first KAP Customer Day in 2006 it turned out that the optional integration of Pico-Satellite separation devices would provide KAP with a further interesting feature enabling to support the CubeSats community with additional launch opportunities. A new single launch separation device called SPL as shown in the following figure has been developed within the frame of the OOV programme by the German company Astro- und Feinwerktechnik GmbH. Several SPLs deployment system depending on the final requests from the CubeSat community can be accommodated on KAP preferably on a LEO application.

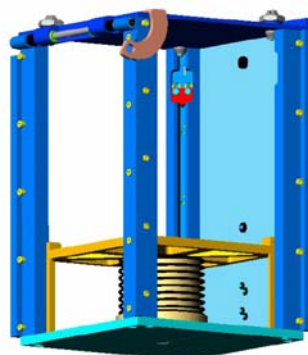


Figure 9: Single PicoSat Launch Device SPL

## THE DEMONSTRATION MISSION IN 2008

The demonstration mission on Ariane ASAP-5 is scheduled for August 2008. A possible accommodation scenario is shown in Figure 6. This ASAP-5 mission has six available empty seats for a potential integration of further experiments and the KAP Kit besides two micro-satellites already fixed as passengers on that mission. For that demonstration flight Kayser-Threde has agreed with Arianespace to have a minimum interfacing mission scenario to the launcher and a maximum re-use of existing design and ground equipment to lower the risk and to have the necessary flexibility due to the existing schedule constraints. Nevertheless, it is planned to realize a maximum mission duration of 7 days to provide maximum in-orbit mission time for the experimenter community on request.

After separation of the main passengers approximately 32 min after lift-off, KAP-DM remains on the ARIANE 5 upper stage in GTO orbit with a spin-rate motion around the launcher longitudinal axes at approximately 10 rpm. The orbital parameters of the KAP-DM are defined by the standard Ariane 5 ECA GTO trajectory as follows: Apogee at 35,950 km / Perigee at 250 km / Orbit inclination 6° / Argument at perigee 178°.

The attitude pointing at separation will be defined by Arianespace according to mission requirement. The thermal and radiation environment requirements for the KAP payloads are preliminary defined and available in the KAP User's Manual meanwhile available on the KAP homepage [5].

The KAP environment is defined by the launcher environment and the final upper stage orbit. A complete set of environmental analyses have been performed to allow defining this environment for the experimental payload especially for the Ariane 5 flight into GTO due to the high radiation environment. Although critical for electronic devices the several passing of the Van-Allen-Belt (having an orbit duration of 10,5h) is interesting for specific scientific exposure tests.

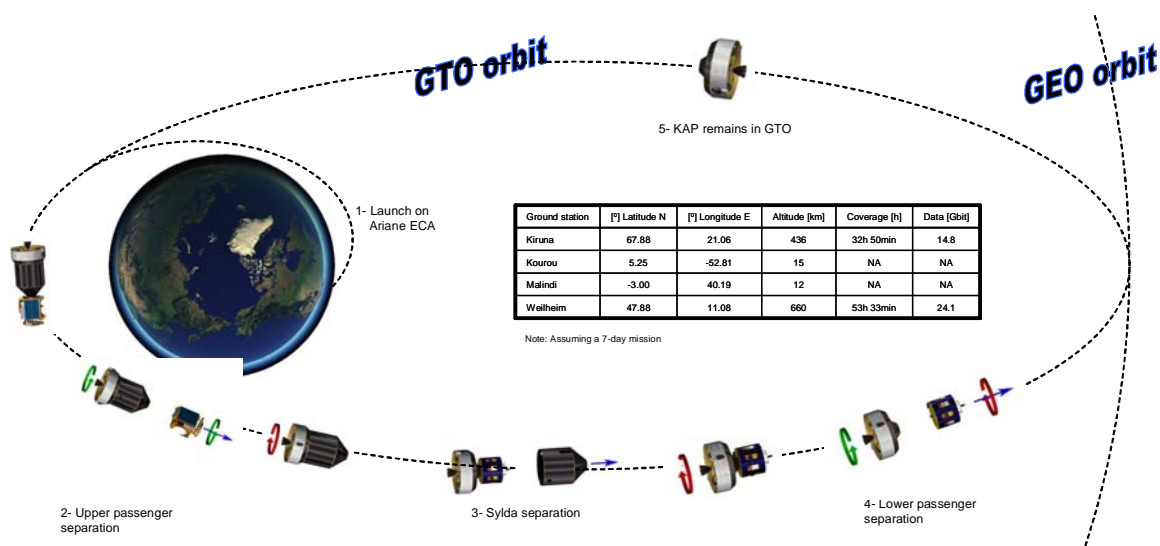


Figure 10: Mission Overview KAP Demonstrator Mission on Ariane 5

A dedicated Call for Interest for the KAP-DM and the KAP programme to be continued step by step on the European Launcher will be published in ESA-EMITS in the 2<sup>nd</sup> quarter of 2007. This Call of Interest will include all necessary information (User Manual, KAP Policy, etc.) about the KAP-DM and gives an outlook on the 2009 and beyond planning. This shall allow for all experimenters to raise its interest without any obligations. Kayser-Threde together with ESA will evaluate all proposals and contact all interesting experimenters to discuss the next steps. It is planned to invite all experimenters to the 2<sup>nd</sup> KAP Customer Day in July 2007.

## PROGRAMMATIC ASPECTS

The main objective of the KAP programme is to provide recurrent flight opportunities for auxiliary payloads as piggy-back solutions on members of the European Launcher Family. 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 level (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 subsystem level (see Figure 11).

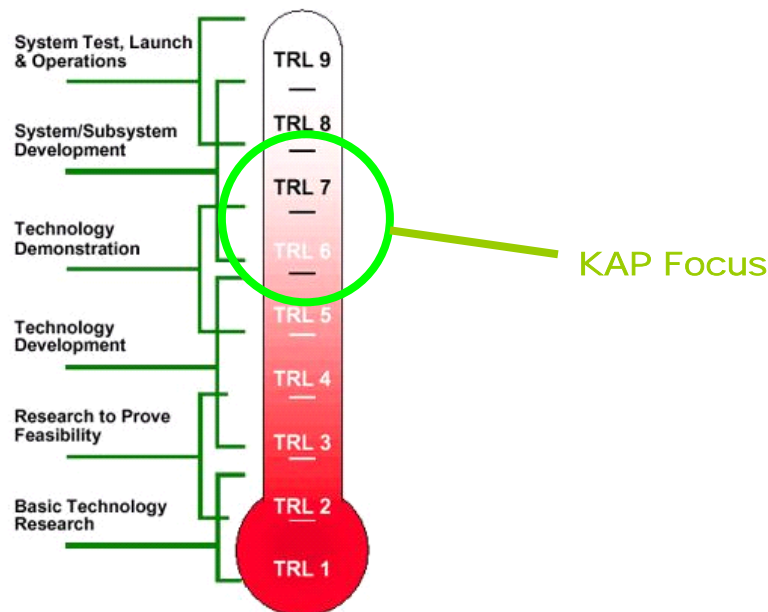


Figure 11: Definition of Technology Readiness Level to be passed before entering of a new technology into real service

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 range missions. A database of both auxiliary payloads and flight opportunities has to be generated, preferably to be maintained by ESA, in order to provide up-to-date information on current and future opportunities. This is one of the objectives of the current Phase B of the Demonstration Mission on Ariane 5. In parallel to that the mission and system requirements shall be specified, and the mission and design concept for the KAP demonstration mission shall be frozen.

Kayser-Threde has collected manifold experience as experiment’s system integrator and partner of the science both in manned and unmanned space business. 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 interface between the auxiliary payloads and the launcher authority. The KAP payload life cycle will cover:

- Experiment’s decision and 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 operation

With the KAP programme Kayser-Threde will provide a full service package to the customer comprising:

- 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 2008, 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. 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 certain mission are ready for integration in due time.

Figure 12 shows the logical flow during the development and industrialization of KAPn from Program Kick-Off to the final in-orbit mission. After a certain acquisition phase which can include a dedicated Call of Interest (like planned for the DM) 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 Program Kick-Off starts the delta-development and industrialization phase of a KAP mission.

In a Delta-Phase B the mission will be specified (depending on the available flight opportunity and the experiments needs) and the necessary design adaptations of the KAP Kit will be identified to be frozen at a specific KAPn Mission Review. Within Delta-Phase C the identified design and interface changes will be implemented and LLI will be procured to secure the schedule. A Delta-CDR shall release the KAP Kit equipment manufacturing and assembly phase called D1. In parallel to that the experimenters will develop and industrialize their flight experiment which may differ from experiment to experiment depending on the design or hardware maturity level existing at Program Kick-Off. Kayser-Threde will follow that parallel activities the experimenters are fully responsible for with specific intermediate inspection and review points as indicated where inputs to the overall system reviews and preliminary verification steps are foreseen.

The overall schedule shall be synchronized between the experimenter and Kayser-Threde to have finally at the same time an acceptance of both KAP Kit subsystems and flight experiments releasing the final KAP system integration and test phase D2. This phase will be finalized by a system acceptance and release for shipping to the launch site. Intermediate storage or waiting periods may occur now. This flexibility on the launch site is necessary to ensure the integration as piggyback payload to the launcher with now impact to the overall launch preparation phase by KAPn itself. Any attendance of the experimenter to the programme in Phase D2 and D3 (final launch site preparation phase) will be agreed case by case based on the specific experiment's needs.

According to Kayser-Threde's experience it is necessary in some cases to start the industrialization of a flight experiment well in advance before starting the dedicated KAPn programme. But having a reliable and recurrent programme such as KAP available, 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. The KAP programme shall provide such a kind of flexibility that a late exchange of payload in case of delays is possible due to standardized interfaces. Kayser-Threde is available for the experimenters as potential customers to support them as early as possible to get on KAP and to select the right flight opportunity depending on the experimenters needs.

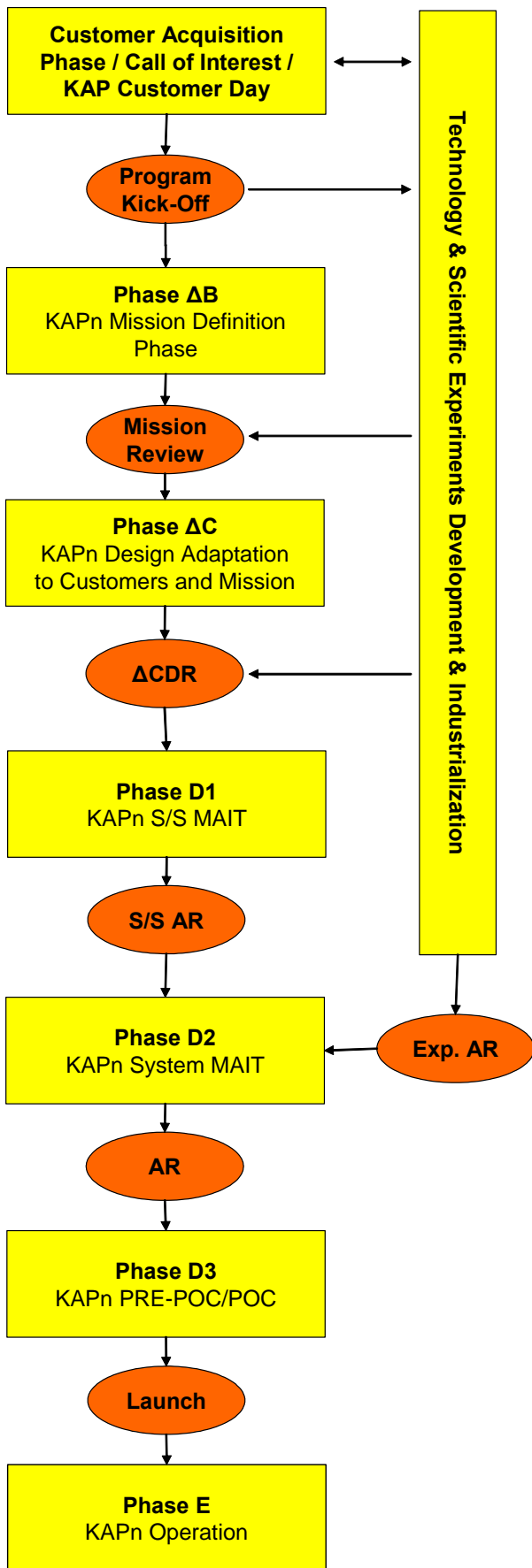


Figure 12: KAPn programme logic

## SUMMARY

Kayser-Threde together with Arianespace has established the concept of a flexible, recurrent and easy access-to-space for auxiliary payloads for in-orbit technology demonstration or exposure to the space environment. The KAP demonstration mission on Ariane ASAP-5 scheduled in August 2008 shall be considered as the first step of a recurrent and sustainable programme for a cost-efficient In-Orbit Test Facility. A Call for Interest will be published in EMITS in the 2<sup>nd</sup> quarter of 2007 in order to announce the KAP programme start. Experimenters are invited to have a look and manifest their interest as early as possible. KAP on SOYUZ and VEGA is the next step to adapt the concept to other European Launchers and provide additional possibilities in LEO finally securing a recurrent programme with at least one flight opportunity per year on altering launchers.

## ACKNOWLEDGEMENT

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