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## **TECHNOLOGY IN-ORBIT DEMONSTRATION USING THE NEW AUXILIARY PAYLOAD PLATFORM KAP ON VEGA**

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### **ABSTRACT**

The development of new technologies for space application goes through several steps defined by the so-called technology readiness level (TRL) before finally being approved to be implemented as real flight hardware. Also if having performed a complete development program including qualification tests on ground, a demonstration of the technology in space under real environmental conditions being exposed to the real launch loads during lift-off is an important step to prove finally the new technology and to demonstrate its ability to work as specified under space environment conditions.

The opportunities for access to space for such kind of In-Orbit-Demonstration are not given regularly and especially Europe has no standard facility like Russia has with FOTON or the U.S. has with the Shuttle. The success of Kayser-Threde's test satellite MAQSAT-B2 for L521 (2<sup>nd</sup> Ariane 5 ECA qualification flight in February 2005) which was equipped with experiments, sensors and an autonomous telemetry (TMA) and experiment infrastructure system has led to the development of a concept of a new experimental platform called KAP (Kayser-Threde Arianespace Platform) in cooperation with Arianespace allowing an efficient access to space for technology in-orbit demonstration and small scientific experiments as auxiliary payload.

KAP as a complete kit of the TMA electronic boxes, power supply and the experiments can be integrated to the launcher payload bay in several configurations: either mounted on a raising cylinder having a platform to accommodate all equipment or mounted on the secondary payload separation platform in both cases underneath the primary passenger's payload adapter. KAP shall serve as a piggy-back solution in the launcher payload bay using remaining launcher payload capacity and stays attached to the upper stage.

This concept developed originally for Ariane 5 shall be expanded to VEGA as the future smaller member of the European Launcher Family. With Ariane 5 launching into GTO VEGA will offer an affordable access to LEO with significant advantages comparing to Ariane 5.

On the experiment infrastructure side KAP has meanwhile two different systems available: the CMA2000 already successfully demonstrated on Ariane 5 and the next generation CTS3000 meanwhile successfully demonstrated in the TEXUS/MAXUS program where Kayser-Threde is also responsible for the payload infrastructure and integration.

## Background

Kayser-Threde has gained meanwhile significant experience with Ariane 5 payload bay activities based on the development and manufacturing of a series of dummy and test satellites (MAQSATs) and structures (MFD) for Ariane 5 since 1997 [1,2,3]. Two examples are shown in the following figures.

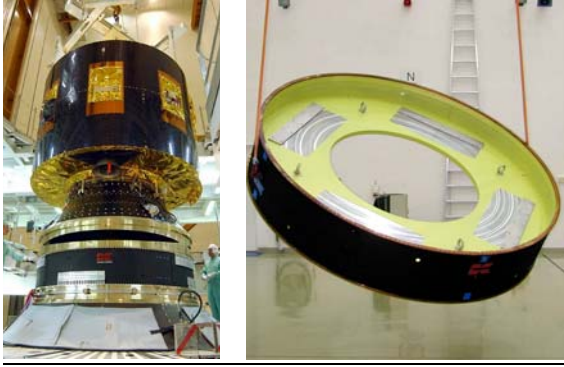


Fig. 1: Multipurpose Fitting Dummy MFD500 on L513 for overall payload mass and CoG adjustment as well as shock damping device.



Fig. 2: MAQSAT-B2 as lower passenger on L521, a 3,5t fully representative test satellite carrying experiments on board and the mini satellite SloshSat on top.

## KAP Baseline Concept on Ariane 5

Already with the MFD-project in 2001 the idea was born together with Arianespace to find a solution for a kind of Ariane 5 standardized piggy back solution for auxiliary payload using the remaining payload capacity of

Ariane 5 ECA which is able to carry up to 10t into space which will not always fully used. The flexibility of the launcher authority to introduce such kind of MFD structures led to the first concept of KAP: to introduce a raising cylinder underneath the ACU like the MFD shown in figure 1 remaining attached to the upper stage and to use the internal platform to mount additional flight hardware on it instead of trim masses – called the baseline design concept of KAP.

This baseline design concept is illustrated in figure 3 and one can identify easily the final location of such a KAP when looking to figure 2 identifying the gap between the ACU and the 3936 cone (yellow arrow). Such kind of platform with identical mechanical design was already part of MAQSAT-B2 (red arrow) and had a successful in-orbit demonstration.

During a Phase A study of KAP three different mission scenarios have been defined to provide maximum flexibility for the market analysis started parallel and ongoing promoting tour. The short mission is derived directly from the MAQSAT-B2 mission providing experiment monitoring during lift-off until upper stage passivation only.

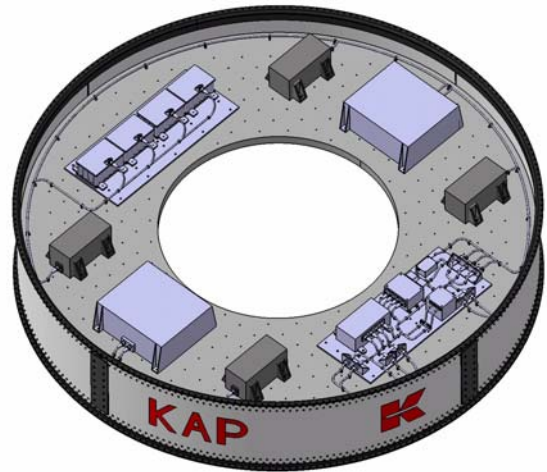


Fig. 3: The KAP Baseline concept using a 2624 mm raising cylinder had already a successful demonstration on L521 as part of L521 and shall later be integrated underneath the ACU in the same way as a MFD (see also Fig.2).

The medium mission is defined to be maximum battery powered providing a mission life time of three days. Depending on the experiment's power need and the maximum use of payload capacity (which can be converted into further batteries if not used)

Name	Duration	Major Characteristics
KAP-SM	3 h (short mission)	Online data transfer with 500 kbps (switch to 100 kbps after fairing separation), power via batteries, <b>220 kg payload*</b> at 600 kg total mass, min. 100W* const. payload power, antennas attached outside of ARIANE (e.g. on ACY), possibility of flight environment monitoring
KAP-MM <i>Baseline</i>	3 days (medium mission)	Data storage and data transfer during playback with 15kbps to GSOC Weilheim, power via batteries, <b>180 kg payload*</b> at 600 kg total mass, min. 25W* average payload power
KAP-LM	1 year (long mission)	Data storage and data transfer during playback with 15kbps to GSOC Weilheim, power via solar generators, <b>180 kg payload</b> at 600 kg total mass, min. 50W average payload power

Table 1: KAP mission scenario overview and baseline mission scenario for KAP on Ariane 5

even more than three days can be realized. Depending on the experimenters need the monitoring and control during lift-off can be switched on or off.

The long mission was identified to have a full compatible system to TET – the future German In-Orbit Demonstration satellite out of DLR’s OOV-program – with the same mission life time envisaged. To realize this, KAP must be updated to a full satellite w.r.t. solar power generation, on-board computer.

From the efficiency point of view the medium mission has been identified as the most realistic one. Nevertheless, the short mission might be of interest especially for testing new launcher technologies combining with measurements of the launcher environment for flight assessments. The long mission will be of highest complexity and highest costs comparing to the other scenarios and is currently seen as option only in the KAP program.

Table 1 shows an overview of the three different mission scenarios identifying also the major technical characteristics.

### Why In-Orbit Demonstration?

Developing a technology (materials, components, devices, etc.) for a potential future space application means one has to follow a certain development logic and plan via several steps or levels. In space business the technology maturity or development status is defined using the so-called Technology Readiness Level (TRL). There are different definitions used by different agencies, although they are somewhat similar. The most common definitions are

those used by the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA). In Europe there is a definition by CNES available. Figure 4 shows the TRL definition by NASA.

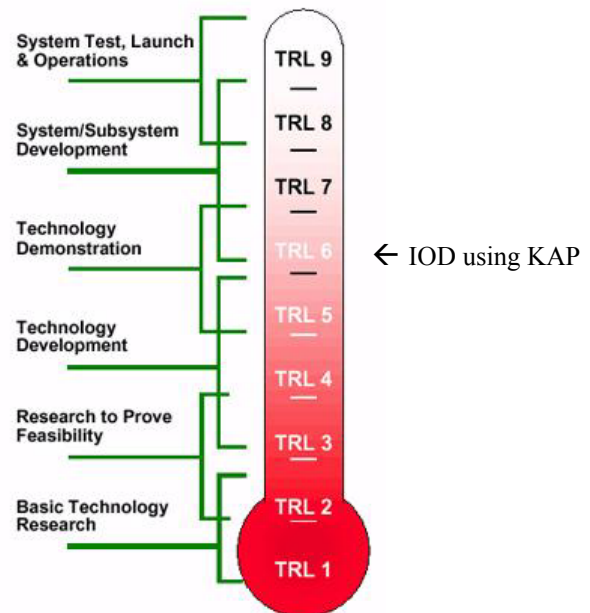


Fig. 4: The Technology Readiness Level definition by NASA with KAP focussing here on level 6.

Not each technology must be demonstrated in space. A qualification test program on ground is able to cover very much aspects w.r.t. e.g. environmental conditions. Nevertheless, for many technologies an IOD is needed and the development responsible is then requested to identify a flight opportunity.

The KAP concept shall serve now as a standardized and recurrent solution for that needed efficient access to space on Ariane 5 as baseline concept and on VEGA as advanced concept.

## **KAP Marketability**

One of the biggest problems for small payloads in Europe is that there is no Europe-wide self-standing program bringing together both, the different flight opportunities and the experimenter's needs. Such a program is well established meanwhile in the United States and there is a clear need to have such a similar program in Europe preferably organized by ESA.

That means, that such an initiative like KAP is not easy to establish due to a kind of hen-egg problem existing in Europe. Due to missing flight opportunities, a lot of experimenters do not see the chance to develop such an experiment to have it available in case of a single flight opportunity suddenly occurs (like the MAGSAT for L521 in 2005). Respective announcements of opportunities of ESA for such single events are often not successful due to that reason. There are a number of new and even critical technologies developed on bread-board basis waiting to be demonstrated in space which would give them the final approval to future space application.

A dedicated AO by the DLR for the German OOV-program for identifying payloads for the TET satellites were very successful receiving answers from more than 60 German institutes and companies. The difference is easy to identify: The AO is embedded in an agency program and TET will not be a single event but minimum two satellites and even more in case of success.

For the planned up-coming Phase B1 of KAP in the frame of the GSTP-4 program it is planned to harmonize the Europe-wide activities for auxiliary payloads and technology In-Orbit-Demonstration together with ESA.

Typical experiments and technologies to be tested on KAP could be: Solar Arrays, Gyros, Electronics, Laser, Antenna, Special Equipment for future scientific missions, Star sensors, Communication equipment, Navigation equipment, GPS, GALILEO equipment, Simple mechanisms, Thermal Equipment, Telemetry Experiments, Heat Pipe Experiment, Video Experiment, Sloshing Experiment, Electronic Drift Analyzer, 3D-Plasma Analyzer, Deployment/Separation

Experiment, Thermal Louvers, Cryo-Cooler, Propulsion Experiments, Batteries, Fuel Cells.

Therefore, the KAP concept logic follows a stringent approach. Scientific and/or technology experiments have the following flight opportunities up to now: single piggy back solutions, manned space flight (e.g. Space Shuttle, EUTEF on ISS), autonomous, free-flying test-satellites and -platforms (STENTOR, TET, etc.), or Russian capsules (FOTON) or Russian launchers.

These options normally provide limited envelope, mass, power, data transfer due to: interface and mission constraints, costs, overall physical budget allocations for the payload. KAP in contrast shall: provide significant higher payload mass and significant larger payload envelope, thus allow for in-orbit demonstration of also large experiments not realizable up to now, be fully autonomous (very limited launcher I/F) but will not be separated, be fully customer oriented, means complete infrastructure will be adapted for experimental payload, lead finally to a cost-efficient solution, be a recurrent standard experimental platform for reliable planning of experiment's flight opportunities, and finally be an European solution for the European Launcher Family

## **KAP Advanced Concept**

The market assessments performed up to now including the output of a first KAP Customer Day in April 2006 has shown, that such kind of program has to provide certain flexibility in terms of applications and mission scenarios keeping always in mind, that a cost-efficient solution – means no free-flying stabilized satellite platform – has to be found. Coming back to the original baseline concept of figure 3 as has been sketched from the early beginning of the KAP initiative in 2002 only specific customer can be addressed, but it was a key to start the discussion and to come to the point where KAP currently is.

With a raising cylinder mounted underneath the ACU of an Ariane 5 primary passenger and KAP remaining attached to the upper stage after passivation the constraints w.r.t. environmental conditions are GTO (high radiation environment) and no micro-gravity environment due to Ariane 5 upper stage

spinning ( $10\text{min}^{-1}$ ) and starting slowly to nutate due to small remaining disturbances.

For a number of experiments these conditions are fine and even appreciated (e.g. testing of electronics). Also future launcher technologies are interested to be demonstrated/qualified on an Ariane 5 launch with the Ariane 5 environment being the harshest and therefore most representative one. But, there have been various other experiments meanwhile identified interesting in LEO applications and micro-gravity conditions.

For a realization in LEO, there have been ideas exchanged with the VEGA-team to accommodate such a raising cylinder in the VEGA payload bay in the same way as for Ariane 5 leading to a potential IOD-system in LEO. Besides some modifications in the telemetry-unit of KAP the concept is in the same range of cost-efficiency as on Ariane 5.

This might change when trying to provide a micro-gravity environment. Here, a clear update of such kind of platform is necessary by adding a simple AOCS able to stabilize KAP being attached to the upper stage. Due to size and mass of the ECA this solution is not possible on Ariane 5. But on VEGA with the much lighter AVUM upper stage such kind of stabilization is feasible as first assessments have shown.

Keeping in mind, that also SOJUZ will join the European Launcher Family when starting to launch from Kourou the following outline of the KAP family concept can be given:

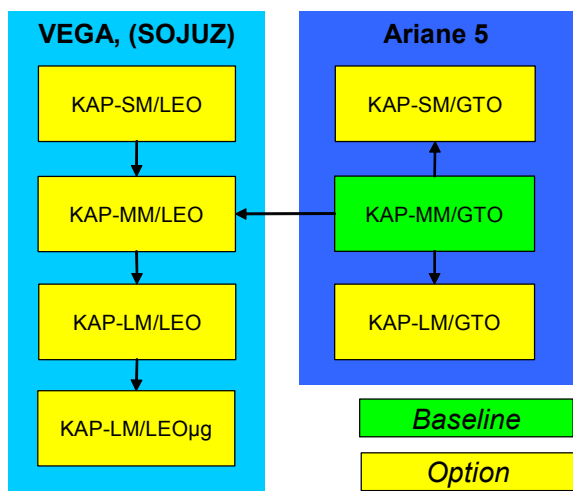


Fig. 5: KAP family concept overview

All the family elements shown in figure 5 are based on the concept of introducing an additional raising cylinder equipped with the TMA, power and the experiments to the payload configuration. The following figure 6 shows the VEGA-KAP and a possible launch configuration of on VEGA. Here, the new standard I/F diameter of 1780 mm has been used for the raising cylinder, which is the future standard I/F diameter for the complete European Launcher Family.

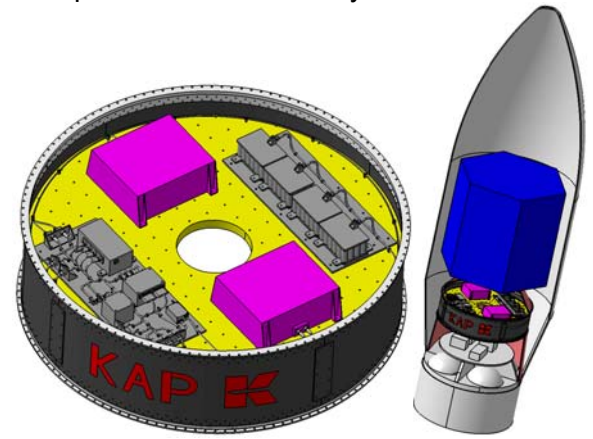


Fig. 6: KAP on VEGA with 1780 mm raising cylinder

The advantage of such kind of concept is that KAP can serve like a black box having identical mechanical properties and performance per launcher type. This means, that e.g. Arianespace as operator of Ariane 5 can easily assess the possibility of adding such a clear defined raising element into a launch configuration having sufficient remaining payload capacity by switching on/off the KAP element in the launcher coupled load analysis.

Another enlargement of the concept is possible, when thinking of KAP as a kind of kit (TMA, power, experiments) to be mounted on a structure for an IOD flight opportunity already existing or suddenly occurring. Typical examples for structures, where a KAP kit can be installed are:

- ASAP5 (recurrent program)
- MAQSAT (single event)
- ACU (recurrent program)

Two examples are given in the following figures. Figure 7 shows the KAP Kit mounted on ASAP5 which accommodates e.g. already two Mini-Satellites. Each ASAP5 provides 8 mounting capabilities resulting in remaining 6 for KAP in such kind of concept scenario.

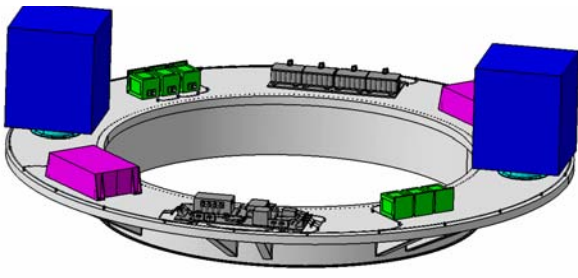


Fig. 7: KAP Kit mounted on ASAP5

Figure 8 shows the KAP Kit mounted on a potential future test satellite for the VEGA demonstration flight program.

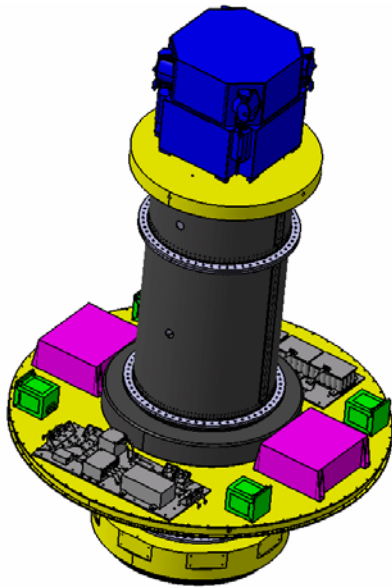


Fig. 8: KAP Kit mounted on ASAP5

A further option is to include CubeSat separation devices (see green boxes on figure 7 and 8). This so-called Single Picosat Launching device is currently under development by the German company Astro Feinwerktechnik and shall be introduced with a first demonstration on KAP [3].

Nevertheless, to bring KAP forward and to establish it as a program for cost-efficient access to space for auxiliary payload and In-Orbit-Demonstration it is necessary to have a clear defined baseline scenario able to be enlarged in the right way with only those elements which are necessary to provide a coherent and marketable program.

### KAP TMA

Heart of the KAP concept is the fully autonomous experiment infrastructure system called TMA providing experiment data

acquisition, experiment control, data storage data telemetry, power supply, etc. There are two options available: The CMA2000 (see figure 9) has already been qualified on Ariane 5 with MAQSAT-B2. A more flexible solution called CTS3000 with a decentralized master/slave concept is available from the successful TEXUS/MAXUS sounding rocket program (see figure10).

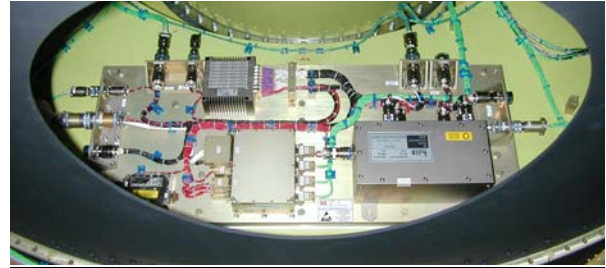


Fig. 9: TMA of MAQSAT-B2 to be used on KAP-SM

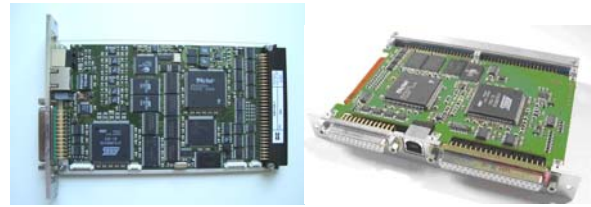


Fig. 10: CTS3000 Master/Slave Module for KAP-MM

More technical details about the TMA concept can be found in [1,2,3,4]. For detailed experiment's interfaces description please refer to the KAP on Ariane 5 User Manual available on the KAP homepage [5].

### References

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