Concurrent AIV and Dynamic Model Strategy in Response to the New Normal of so called Death March Projects!

– The Engineering Venture as Experienced in the DLR MASCOT and Hayabusa-2 Project –

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ABSTRACT

As today's projects increase quickly in complexity and development times are shortened to save budgets, the term "Death March Project" has been recently used to describe projects which schedules are so compressed that current and well established processes cannot be followed in order to finalize the project in the given time. MASCOT, a small 11 kg Asteroid Landing Package on-board JAXA's Hayabusa-2 space probe is currently being finalized at DLR. Its last stages during the Assembly, Integration and Verification (AIV) process show that by applying a unique mix of conventional and tailored Model Philosophies it is possible to dynamical adapt the test program, limited by a fixed launch date, to accomplish for the shortest planning and a suitable weighing of costs and risks. Introducing "Concurrent AIV" to identify and mitigate design and manufacturing issues shortened the MASCOT project timeline further from a general 4 year AIV phase to less than 2 years.

KEY WORDS: MASCOT, Hayabusa-2, Asteroid Lander, Concurrent AIV, Dynamic Model Philosophy

INTRODUCTION

About the size of a shoe box and weighing roughly 11 kilograms, the Mobile Asteroid Surface Scout (MASCOT) is a small landing package aboard the Japanese space probe Hayabusa-2 (HY-2), scheduled for launch in December 2014. MASCOT is currently being finalized at the German Aerospace Center (DLR) in close collaboration with the French space agency (CNES) and the Japanese Aerospace Exploration Agency (JAXA). The 5-year sample return mission Hayabusa-2 targets the carbonaceous Near-Earth Asteroid 1999 JU3, an object belonging to the most abundant type of space rock in our solar system which is thought to contain water and therefore may have provided the building blocks for seeding life on Earth (Alexander et al. 2012). The fully autonomous robot MASCOT will carry a complementary set of scientific payloads to study the temperature, chemical composition, surface texture and magnetic properties of this asteroid.

Originally investigated in the framework of the European Marco Polo study, MASCOT has undergone several concept iterations converging into a system which is very compact in design but still achieving a high ratio of Payload mass (3 kg) to Total System mass (11 kg). Following an invitation from JAXA to join in the follow-up mission of the first asteroid sampler Hayabusa, MASCOT was selected at a time where its final conceptual design, including its scientific payloads, had not yet been fully defined. The tight schedule, tightly defined envelope, and strict margins policy were challenges during the development at all levels. Science payloads, bus subsystem units and overall system design had to be derived from what was available off the shelf at the project partners' in very heterogeneous maturity levels ranging from concept study to flight heritage hardware. As shown in **Figure 1**, MASCOT was in the beginning behind the main spacecraft schedule, but due to the early delivery date of the FM the project development cycle needed to be shortened. In other words, the MASCOT development was required to constantly catch up with the master timeline and finally overtake it (Lange et al. 2012).

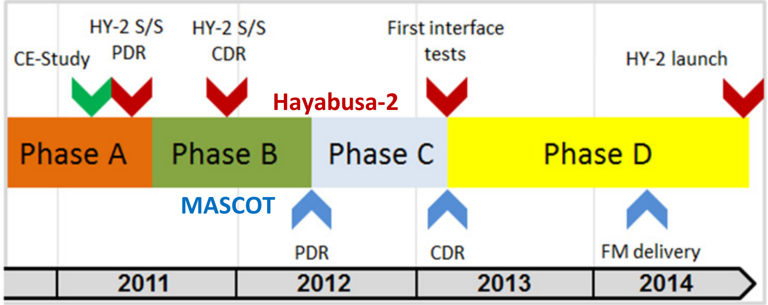

Figure 1: MASCOT project timeline with major milestones

MASCOT entered the realm of hardware with the first unit breadboarding in June 2011, over half a year before formal go-ahead. It passed Hayabusa-2 subsystem CDR in December 2011, and an internal system PDR in July 2012. The final go-ahead was given after passing the internal system CDR in April 2013. According to current planning, the MASCOT flight model will be delivered in May 2014 for launch in December 2014. The tight schedule, due to a launch date fixed by celestial mechanics, was one of the major challenges during the MASCOT development not possible with the current established verification strategies, but with a controlled Death March (Yourdon 2003).

THE MASCOT MISSION

Hayabusa-2 will launch from Tanegashima Space Center and arrive at 1999 JU3 in June 2018. After arrival, HY-2 will first perform a global mapping in order to characterize the asteroid. With the landing site selected based on local geology and thermal constraints, MASCOT will be released to the surface, either during a dedicated descent or during one of the sampling dress rehearsal maneuvers. The mothership will descend to the separation altitude of 100 meter, at which point MASCOT will be ejected via a spring mechanism with a controlled low velocity in the order of cm/s (**Figure 3**). MASCOT will fall to the asteroid surface under the effects of the weak gravitational field, before landing in an unknown orientation. In order to start the investigation, MASCOT must be orientated to its primary surface side. This is performed by an up-righting manoeuver using an internal mobility mechanism. A full complement of scientific activities will be performed, involving approximately one asteroid day, before MASCOT can be relocated to another site by initiating an uncontrolled hop of up to 200 meters across the surface. Further scientific activities will take place, and then, power depending, a second hop is considered. The expected lifetime of MASCOT is between 12-16 hours due to its single battery energy supply. MASCOT takes up a key role in the HY-2 mission aiming to conduct the first ever in-situ measurements on an asteroid providing ground truth information, since rocks nature (i.e. volatiles within rocks) can change during return flight. MASCOT's suite of science instruments, namely the Radiometer (MARA), the wide angle visible/infrared camera (CAM), the Magnetometer (MAG) and the hyper spectral infrared Microscope (MMEGA), are designed to study the target asteroid with a focus on surface properties and the close-in space environment (**Figure 2**). The design goal is to provide supporting information to the process of sampling site selection. MASCOT acts therefore as scouting vehicle in favor of the mother spacecraft, but in addition its measurements are on different length scales. The returned samples by Hayabusa-2 will be in the micro- to millimeter scale, whereas the orbiter will map the asteroid from several meters to a few centimeters scale. MASCOT's measurements will complete this picture with measurements in ranges from micrometers to several centimeters scale and hence, providing the context of any collected samples.

Figure 3: MASCOT STM-1 on display at the ILA Berlin Air Show 2012 showing the moment of separation from Hayabusa-2

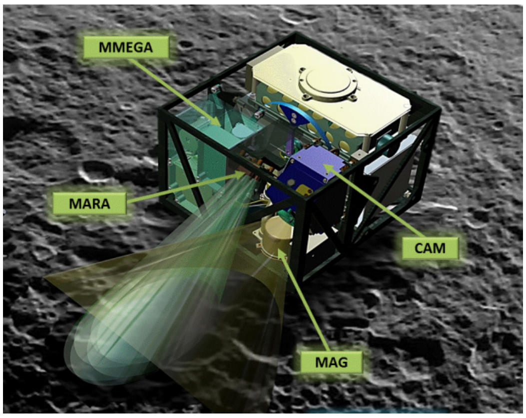

Figure 2: Artists impression of the landed MASCOT on the surface of 1999 JU3 indicating the operation of its 4 payloads.

THE AIV PROGRAM

The Assembly, Integration and Test/Verification (AIT/AIV) is the final stage in producing a spacecraft and readying it for launch. It includes the simulation and test of the expected space environment and flight operation to verify and demonstrate the overall performance and reliability of the flight system. Choosing the right philosophy or approach of the Verification and Validation (V&V) process is crucial and driven by risk tolerance. Less verification implies but does not necessarily create more risk. More verification implies but does not guarantee less risk (Larson et al. 2009).

Model Philosophy – Dynamic and Flexible

In European and American space industry there are currently two main model philosophies in use to conduct the verification of a space system. These two philosophies are known as the ***Prototype Approach***, sometimes also called the Traditional or Classical Approach, and the ***Protoflight Approach*** (Ley, Wittmann and Hallmann 2009) and (ECSS 2010). The basic difference is reflected in the number and types of models being built and tested. In the Classical Approach the design verification evolves in a mostly sequential and also successive fashion from a Dummy Model, a Structural or Structural-Thermal Model (STM), an Engineering/Electrical Model (EM), a Qualification Model (QM), to the final Flight Model (FM), which may also have a sister model used as Flight Spare (FS) in case of launch failure or otherwise as Ground Reference Model (GRM). The Protoflight Approach qualifies the design of a single flight model by replacing critical subsystems during the integration process. The Protoflight Model (PFM) is subject to a full qualification process and is refurbished before launch. It is generally faster and cheaper and is applied to projects with no technology critical design accepting a medium risk.

The classical approach would be of course the most reliable method to choose as it gives the highest confidence that the final product performs well in all aspects of the mission. However, due to the tight schedule in the MASCOT project, the extensive and time consuming method of this approach could not be applied. On the other hand, the Protoflight Approach was also not applicable, since the chosen payloads and the system itself had very heterogeneous maturity levels, which prevented the system from being tested as a consistent entity at each stage. Hence, the test philosophy of MASCOT applied a ***Hybrid Approach*** with a mixture of conventional and tailored model strategies. This approach is common practice in scientific robotic missions (Larson et al. 2009) but the specific MASCOT model philosophy goes even further. The project started with a baseline on the Classical Approach (STM, QM and FM) to ensure a minimum number of physical models required to achieve confidence in the product verification with the shortest planning and a suitable weighing of costs and risks. But this approach was adapted on a case by case scenario, where the model philosophy evolved along the verification and test process depending on the particular system and subsystem readiness. According to this dynamical process, the decision which model to test and what to test with it was often made simply on the subsystems availability. This included test models reorganization, refurbishing and re-assigning previous models for other verification tasks if appropriate, skipping test cases, parallel testing of similar or equal models and for some components allowing the qualification on MASCOT system level.

The verification approach was focused around the systems main structure which comprises the MASCOT Landing Module (LM) the Mechanical and Electronic Support System (MESS), which is the main interface to HY-2 remaining at the spacecraft after separation, and the common electronic box (Ebox), which is an integral part of the LM structure serving also as interface for other subsystems like the mobility unit, the battery and the communication modules. The development status of these three elements defined the overall maturity of each MASCOT model.

Concurrent AIV – Dealing with Projects Risks

As mentioned before, MASCOT was granted only a limited time which could not hold a classical sequential approach regarding development, test and verification phases or even allowing margins for risks such as coping with delays due to non-conformances on systems, units, parts and facilities. The heterogeneous maturity levels have let to tailor a mixed model philosophy of the subunits into an adaptable overall MASCOT strategy to maintain reduced programmatic risks. Due to the highly compact and lightweight nature of this system almost all elements are custom made for the specific mission scenario. The risk assessment showed that a high chance for schedule delays can occur due to test repetition of unit failures and late delivery. Keeping this course, the complete path would have taken approximately 48 month. However, when your ride has minimal options to wait for you defining a time limit less than 24 month and none of the subunits are replaceable by off-the-shelf equipment, how do you proceed?

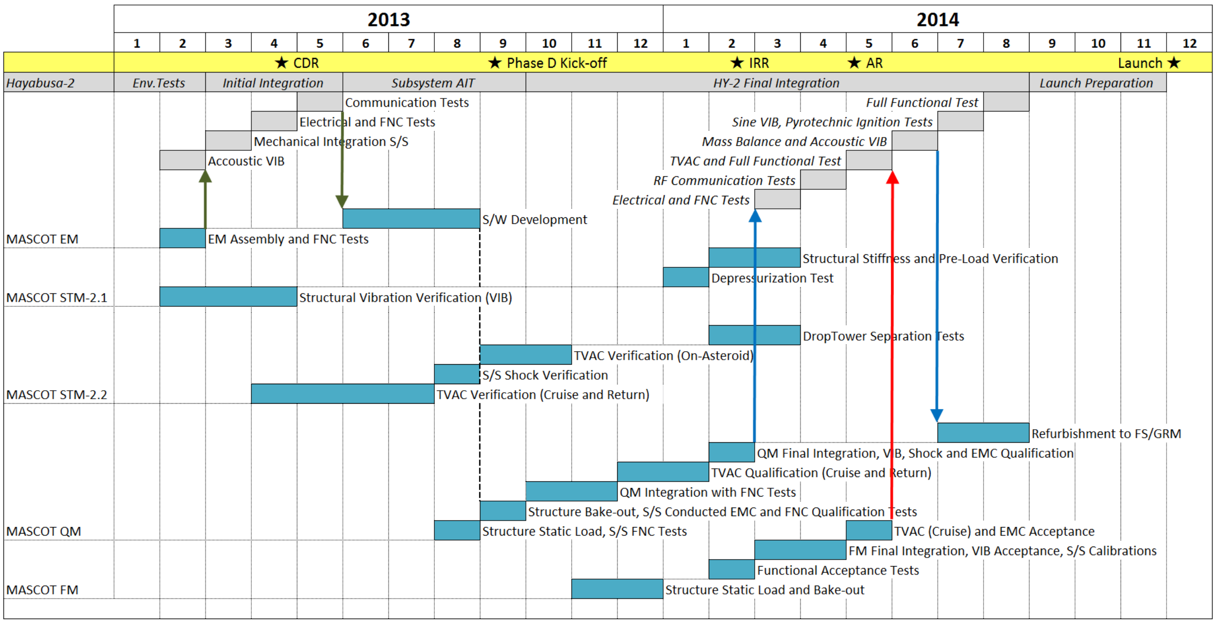

Figure 4: Concurrent AIV schedule as performed in the MASCOT project.

To catch up with the HY-2 development schedule and maintain enough margins to incorporate risk, the MASCOT project incorporated parallelization of testing activities using identical copies and flexibility in its model philosophy. This in turn created independent unique test threads only joining their dependencies at key points where optional other roads could be chosen. In example, if a structure was damaged by one test, or in use longer by another, a copy was shortly available to redo the test if applicable, knowing that a new structure manufacturing process would have taken otherwise 4 months or more. Like Concurrent Engineering, a methodology based on the parallelization of engineering tasks nowadays used for optimizing and shorten design cycles in early project phases, we introduce here the term "***Concurrent AIV***" to express the many simultaneous running test and verification activities (**Figure 4**).

In effect, the development, test and verification track of Software Development, Functional Testing, Mechanical AIV and Thermal AIV got their own independent routes sharing their verification processes. Almost all environmental and functional tests with subsystems could be performed on EM and STM level before the QM and FM were fully assembled which effectively reduced potential delays. In addition, both these final threads (QM/FM – performed in near parallel activities) are sharing again their verification processes. The QM will endure all environmental qualification tests at DLR herewith validating parts of the FM which in turn does its final mechanical and electrical acceptance on HY-2 system level, hereby reducing again required project timeline. Knowing the advantages of this novel approach, the challenges in creating parallel development lines were found in team and facility resources if these are not readily and on-demand available. In addition, this philosophy is also more complex as it requires the overview of the development process of the mother spacecraft, the ongoing progress on system level as well as the insight in all payloads and subsystems. This was handled by splitting the tasks on more Systems Engineering and AIV responsible personnel and performing regular consolidation gatherings between these key player including also the Project Management and Product Assurance, in order to keep the project sorted and on course. Over the last year, these gatherings were held daily, strictly limited in time and based mainly on current test schedules and observed non-conformances. This allowed the core team to quickly react on critical matters saving valuable time usually lost easily in hierarchy driven decision processes.

TEST CAMPAIGNS

The applied approach is dynamic and evolved while the project progressed. As mentioned before, the test philosophy was adapted on a case by case scenario, which effectively reduced the overall development time. However, the situation was complicated since for the verification of the main spacecraft, MASCOT had to take part in certain verification activities on HY-2 system level. In addition to the already parallelized MASCOT test threads, these tasks where scheduled as well in parallel, which introduced a dual-track test scenario. To cope this situation, duplicate or reduced models where built as “built to purpose and schedule”. Nevertheless, this was used as an advantage to shorten the verification process for MASCOT by skipping some safety driven *high priority tests*, which were later performed on the HY-2 system level track. The MASCOT track could therefore also incorporate *lower priority tests* mainly driven by the scientific instruments.

MASCOT Track - Engineering Thoughts face Reality!

The first model built was a breadboard (BB) model consisting of the aforementioned three elements LM, MESS and Ebox, including mass dummies of the single heaviest subsystems, namely the payloads, the battery and the mobility unit. This model was used to initially demonstrate structural integrity on reduced vibration levels. After this test, the MESS and Ebox where refurbished and advanced to an STM, whereas the LM was re-used as demonstration model for the mobility subsystem including pendulum test and parabolic flight. The MASCOT STM-1 then featured the previous BB MESS and Ebox as well as a new LM structure. The model, including also the previous S/S mass dummies, was intended to qualify the structural design, but after failing the test structural damage was severe and it was decided to build yet another structure (STM-2). The STM-1, however, was refurbished and re-used as demonstration platform for the systems separation mechanism needed later in-orbit operation to push out the landing module out of the MESS and HY-2. These tests have been performed in parabolic flight as well as in drop tower experiments. In addition, the STM-1, though structurally altered, was advanced to represent the initial thermal design of the flight model. The model then underwent a reduced thermal campaign for the Cruise Phase (Earth to Asteroid) and the Return Phase (Asteroid to Earth) whereas the return phase was conducted first due to model and setup simplicity. This campaign, though not applicable for qualification, was a valuable dress rehearsal to validate the subsequent qualification and acceptance program. This included test technique, procedures, training of test personnel, logistics, equipment, instrumentation and software.

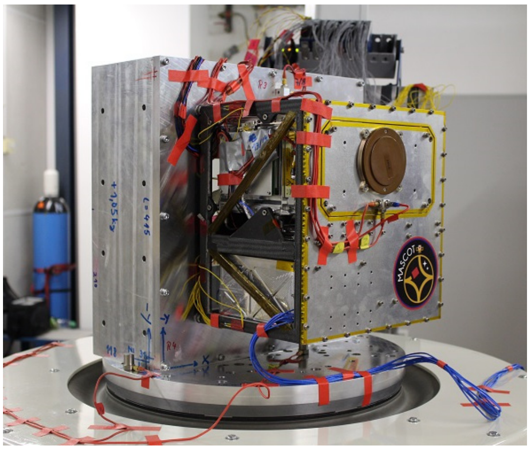

Figure 6: MASCOT STM-2.1 during Random Vibration Test

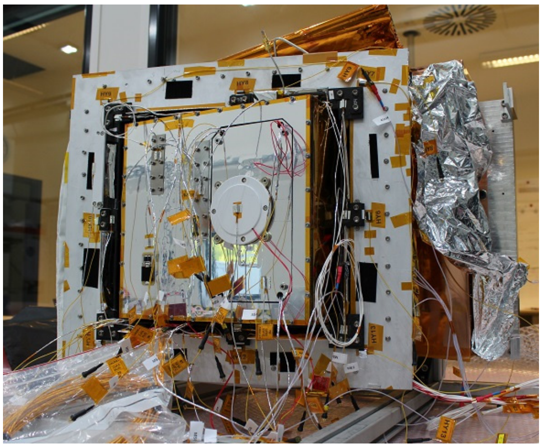

Figure 5: MASCOT STM-2.2 during Cruise-Phase Thermal Vacuum Test.

Due to the fact that structural integrity could not been approved early and the project schedule was too short to account for successive structural and thermal verification, two identical models of the iterated and improved STM were produced (STM-2.1 and STM-2.2) which could run completely independent paths of structural and thermal qualification activities (**Figure 6** and **Figure 5**). Due to similarity in design, by testing one sub-aspect (e.g. structure) at one model, meant verification of this aspect in the other model as well but without testing. For the next vibration campaign with qualification levels, which verified also the frequency response and load levels of all subunits, the STM-2.1 was integrated with the now available P/L, battery and communication STM subunits as well as an EM mobility unit. To shorten subunit test schedules, this test gave also the first possibility for subsystems electronics, if ready, to be integrated into the Ebox to qualify for structural integrity on MASCOT system level.

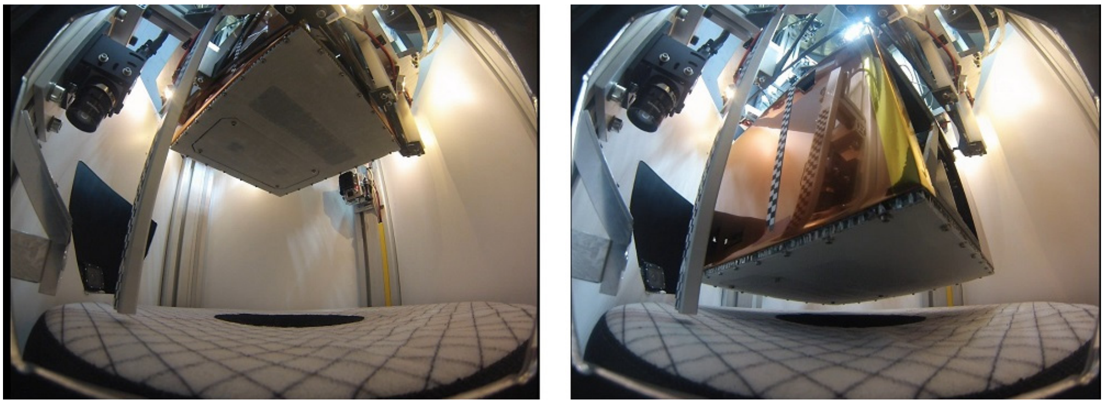

Figure 7: Separation sequence of MASCOT in microgravity during drop tower experiments.

While the STM-2.1 underwent the structural verification path, the STM-2.2 unit was prepared for thermal verification of the Return and Cruise Phase. Therefore, shortly after the vibration campaign of STM-2.1, P/L's and other subunits were re-used and quickly advanced to be thermally representative, including dummy heat pipes, main and sub radiator, optical face sheets, multi-layer insulation as well as controlled heaters. After successful test of the return and cruise phase configuration the setup was changed to the third and final On-Asteroid Phase, whereas this test was again a reduced dress rehearsal for the later QM test which included full functional subsystems and payloads. Both STM-2 units after completion of the structural and thermal path were used as qualification test bed of other critical system elements, in example the separation mechanism (**Figure 7**), preload release, umbilical connector and depressurization as well as P/L FOV alignment tests.

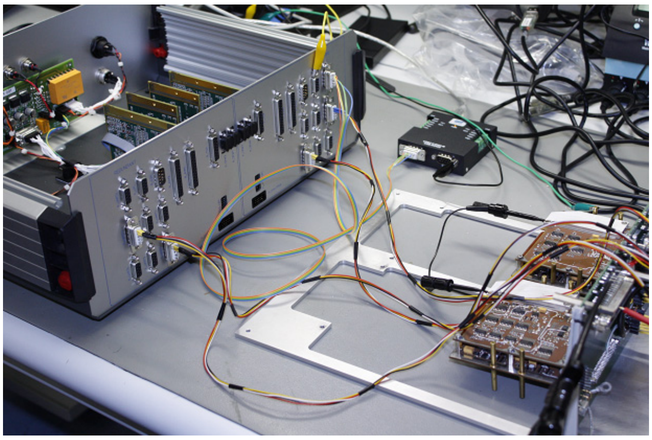

Figure 8: MASCOT SDVF during conducted EMC tests including On-Board Computer (OBC) and Power Distribution and Control Unit (PDCU).

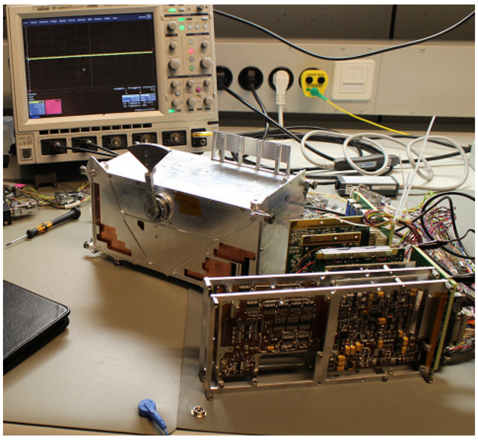

Figure 9: Software verification test of the MASCOT mobility motor and its control unit.

In addition to the physical MASCOT models a Software Development and Verification Facility (SDVF) was created to establish a general test bed for Mascot onboard software development and individual instrument and subsystem software functional tests with real Hardware-in-the-loop electronic (**Figure 8**). This device builds the electrical interface for the system electronic boards including backplane, P/L boards, onboard computer (OBC) and power control and distribution unit (PCDU). The SDVF can therefore simulate certain spacecraft components and their interface by software connected with the only available hardware to be tested at that time. This way, every payload and subsystem can freely do debugging tests which can take longer time independently. In example, the OBC can be connected to the SDVF simulating the other system elements, which could be added piece vise when the hardware electronic becomes available but also the other way around where the OBC remains simulated by the SDVF. In a final step the real OBC board could be integrated running real EM boards and verifying MASCOT's functional performance (**Figure 9**). These functional tests did run continuously until functional performance of all real hardware electronic boards were approved and the cards could be implemented into the MASCOT QM (**Figure 4**). With this approach, most of the problems on the interface and functional of each subsystem were found before the final integration. It reduces a lot of integration problems and troubleshooting time of MASCOT during integration and test.

Hayabusa-2 Track – Bringing it on the Road!

As mentioned above, the MASCOT system tries to catch up with the development progress of the mother spacecraft Hayabusa-2, whose final test sequence is split into sequential test campaigns starting with an environmental campaign with qualification test and the Initial Integration Test (IIT), where subunits were integrated for the first time and end-to-end tested for communication to the main spacecraft. This is followed by an Acceptance Environmental Test

(AET) and the Final Integration Test (FIT) leading all the way up to the launch campaign. Each test campaign is required to see a MASCOT model in order to verify the HY-2 system performance. However, as the MASCOT system only recently reached proper maturity (beginning of 2014), which is just in time to take part in the FIT, reduced models and mock-ups of MASCOT build to schedule and purpose had to be produced.

In order to receive appropriate vibration qualification levels at the final integration place of MASCOT, a dedicated mass dummy (MD) was created resembling the overall MASCOT system in mass, CoG and mechanical interfaces to HY-2. This MD was send to the JAXA/ISAS test center to take part in the first environmental test of the mother spacecraft. For the IIT a separate EM was built with a mock-up structure resembling MASCOT in form and fit as well as having EM functional communications equipment including OBC, PCDU, Antenna and CCOM (**Figure 10** and **Figure 11**). Other subunits were either simulated only by load resistors to test the current drains or replaced by mass dummies to suit the overall weight and handling of MASCOT as a whole. Prior to shipping, an EMC conduction test on the Ebox, including BB/EM/QM electronic cards of all P/L, as well as an initial RF Test had shown basic functional performance. After the conclusion of the IIT the MASCOT EM was send back and was re-used as training model for fit checks and integration processes.

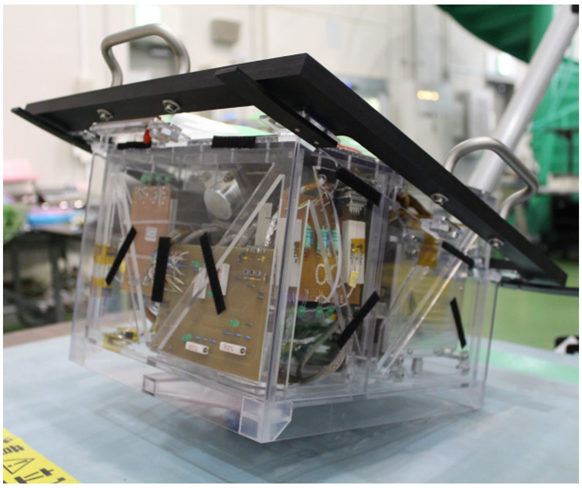

Figure 10: MASCOT EM as used during the first functional tests at JAXA/ISAS verifying basic communication and subunit performances.

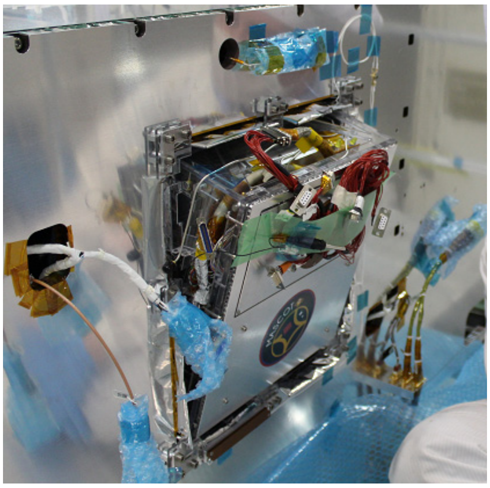

Figure 11: MASCOT EM mounted to the HY-2 spacecraft during Initial Integration Test.

Final Verification Track – When it all comes together!

At the time of writing of this paper, the MASCOT QM has passed successfully the full qualification program with a mix of integrated STM, EM, EQM, and QM payloads and subsystems (**Figure 13** and **Figure 12**). This program included static load tests, full random vibration and shock tests, thermal vacuum tests of all major mission phases (Cruise Phase, On-asteroid Phase and Return Phase), conducted and radiated electromagnetic compatibility (EMC) tests as well as full functional tests (FFT) in table top configuration as well as fully implemented into the MASCOT system. The MASCOT QM currently awaits shipment to ISAS to be included in the AET/FIT campaigns of the mother spacecraft attending additional functional and environmental acceptance test on spacecraft system level. The MASCOT FM, then including all

FM units, will be integrated and prepared for an abbreviated acceptance test program, including vibration, thermal vacuum cruise phase, EMC tests as well as calibration campaigns for payloads and instruments. The FM is then send to ISAS to take the place of the QM, which will be returned to DLR to be refurbished to the Flight Spare unit, and will complete the verification process on-board its mother spacecraft. At this point, MASCOT overtakes the HY-2 development progress and the dual-test track of MASCOT and HY-2 merge. After last functional checkouts, a final integration of MASCOT and inserting late access equipment (e.g. battery), MASCOT will await completion of HY-2 and shipping to Tanegashima Spaceport for Hayabusa-2 launch campaign with a dedicated launch date currently scheduled for December 5, 2014.

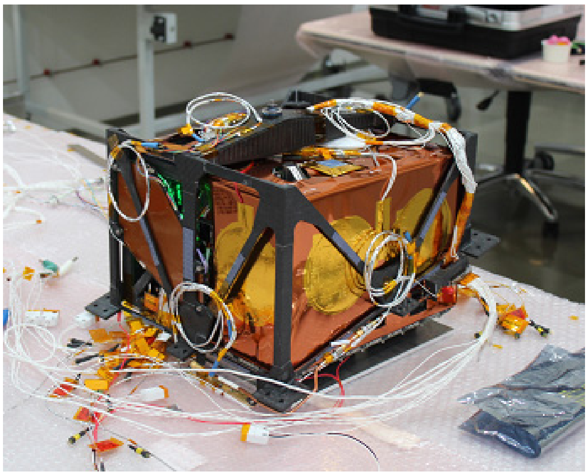

Figure 13: Short functional test of the MASCOT QM after final integration.

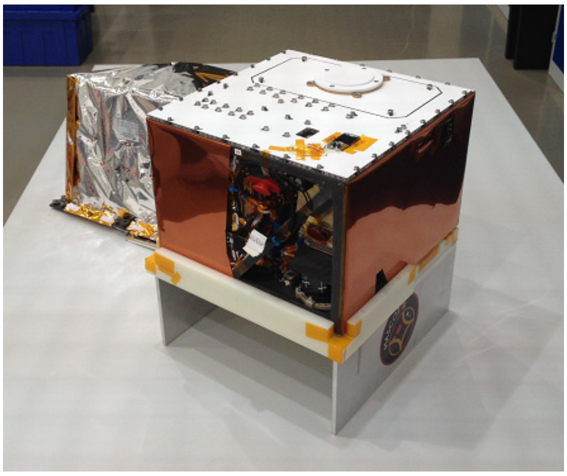

Figure 12: MASCOT QM after passing successfully its Thermal Vacuum and Random Vibration test.

CONCLUSION

A fast paced and high performance deep space project, like MASCOT, faces many challenges specifically during the last development stages. A standard classical model and test approach would have taken too long, but by applying a unique mix of conventional and tailored model philosophies it was possible to dynamical adapt the test program, limited by a fixed launch date, to accomplish for the shortest planning and a suitable weighing of costs and risks. In addition, using Concurrent AIV to identify design and manufacturing issues shortened the project timeline further and keeping an acceptable amount of risk improving MASCOT every step of the way. In effect, a general 4 year AIV phase was reduced to less than 2 years. The challenge of such a compressed schedule (***Death March Approach***) was to identify the test dependencies, test sequences and which test could be performed in parallel.

Nevertheless, in these 2 years the MASCOT team will have successfully completed **30** MASCOT system level tests, including Shock (2) and Vibration (7), Thermal Vacuum (11), Full System Functional (3), EMC (2) and Integration campaigns (5). On Hayabusa-2 system level, MASCOT will have seen additionally **8** tests campaigns for Sinusoidal Vibration and Mass Balance (2), Acoustic Vibration (2), Thermal Vacuum (1) and System End-to-End tests (3). To develop the MASCOT system and to make it flight ready **43** additional System Unit tests were performed, including the Structure (8), thermal Heat Pipes (5), Umbilical Connector (10), Preload Release and Stiffness Change (9) Separation Mechanism (5), Depressurization (2), Antenna Performance (2) and EMC for the common electronic box (2). This ***excludes*** any test performed by the Payloads or other subsystems provided by the collaborating partners and contractors during subunit development. However, the MASCOT team performed countless of unit debugging tests with these systems to help fixing unit level interface problems including campaigns with Power Supply (6), Communication (10), Mobility (4), GNC (3), Camera (6), MARA (3), MAG (3) and MMEGA (2).

Due to its demanding goal and pioneering approach, MASCOT has a high potential to act as a showcase model for projects with a similar demand in high performance and short development time, for example as is the case within this fresh and dynamically expanding field of science. As Near-Earth Asteroids are discovered at an increasing rate, the application of this design approach may one day turn from a rare and welcome launch opportunity to an urgent necessity.

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REFERENCES

Alexander, C. M. O'D. et al.: The Provenances of Asteroids, and Their Contributions to the Volatile Inventories of the Terrestrial Planets, Science Magazine, Vol. 337 No. 6095 (2012) pp. 721-723.

ECSS: Space Engineering – Verification Guidelines, ECSS-E-HB-10-02A, ESA Requirements and Standards Division, 2010.

Lange, C., et al.: "How to build a 10 kg autonomous Asteroid landing package with 3 kg of instruments in 6 years?" – Systems Engineering challenges of a high-density deep space system in the DLR MASCOT project, 2624640 (1325), SECESA 2012.

Larson, J.W., et al.: Applied Space Systems Engineering, Space Technology Series, McGraw-Hill Companies, Inc., 2009.

Ley, W., Wittmann, K., Hallmann, W.: Handbook of Space Technology, John Wiley & Sons, Ltd., 2009.

Yourdon, E.: Death March, 2nd ed., Yourdon Press Series, 2003

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