Towards M5 Call
Technical and programmatic aspects

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Programmatic assumptions: ESA CaC

M5 is a regular M-class mission, with ESA ceiling Cost at Completion below 550 M€ e.c. 2015

- Excludes provision from Member States and partners (if any)
- Typical breakdown of ESA CaC, assuming ESA in charge of operations and launch

Space segment:	52%	(Industrial devpt, incl. contingency)
MOC & SOC:	15%	(ROM, mission dependent)
ESA Project:	10%	(typical)
Launcher:	13%	(Ariane 62 assumed)
Contingency:	10%	(typical at adoption)

With the above breakdown, the industrial cost for ESA provided elements (including payload contribution if any) would be ~ 290 M€.

Mission nominally simpler than Euclid (M2) and Plato (M3), for which industrial cost estimates are in the range 330-350 M€.

Programmatic assumptions: Tentative schedule and selection process

- Call issue date: T0 = Spring 2016 (tbc)
- Candidate selection: T0 + 1 year

  As for M4, a programmatic pre-screening of the mission proposals will be made by ESA and missions outside M5 boundaries will not be considered further

  Up to 3 candidate missions could be selected
- Phase A kick-off: End 2017
- M5 selection: June 2019

  Mission selection review in ~ April 2019
- M5 adoption: June 2021

  Mission adoption review in ~ April 2021
- Launch: 2029/2030 (mission dependent)

Technology Readiness

As for all M-missions, the mission concept should essentially rely on available technologies. TRL > 5/6 is targeted for the Mission Adoption for the space segment.

- In practice, confidence in reaching TRL 5/6 must be reached at the mission selection review (Q1 2019)
- Some technology development activities and pre-developments are possible. In practice, effectively limited to 2-3 years for ESA developments.
- Early identification of the payload consortium core team and lead funding Agencies enables a timely implementation of technology validation activities for the payload. However, Member States funding can be expected to be rather limited prior to M5 selection (mid-2019)

Recall of ISO TRL definitions (1/2)

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 1: Basic principles observed and reported	Potential applications are identified following basic observations but element concept not yet formulated.	Expression of the basic principles intended for use. Identification of potential applications.
TRL 2: Technology concept and/or application formulated	Formulation of potential applications and preliminary element concept. No proof of concept yet.	Formulation of potential applications. Preliminary conceptual design of the element, providing understanding of how the basic principles would be used.
TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept	Element concept is elaborated and expected performance is demonstrated through analytical models supported by experimental data/characteristics.	Preliminary performance requirements (can target several missions) including definition of functional performance requirements. Conceptual design of the element. Experimental data inputs, laboratory-based experiment definition and results. Element analytical models for the proof-of-concept.
TRL 4: Component and/or breadboard functional verification in laboratory environment	Element functional performance is demonstrated by breadboard testing in laboratory environment.	Preliminary performance requirements (can target several missions) with definition of functional performance requirements. Conceptual design of the element. Functional performance test plan. Breadboard definition for the functional performance verification. Breadboard test reports.

Recall of ISO TRL definitions (2/2)

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 5: Component and/or breadboard critical function verification in a relevant environment	Critical functions of the element are identified and the associated relevant environment is defined. Breadboards not full-scale are built for verifying the performance through testing in the relevant environment, subject to scaling effects.	Preliminary definition of performance requirements and of the relevant environment. Identification and analysis of the element critical functions. Preliminary design of the element, supported by appropriate models for the critical functions verification. Critical function test plan. Analysis of scaling effects. Breadboard definition for the critical function verification. Breadboard test reports.
TRL 6: Model demonstrating the critical functions of the element in a relevant environment	Critical functions of the element are verified, performance is demonstrated in the relevant environment and representative model(s) in form, fit and function.	Definition of performance requirements and of the relevant environment. Identification and analysis of the element critical functions. Design of the element, supported by appropriate models for the critical functions verification. Critical function test plan. Model definition for the critical function verifications. Model test reports.
TRL 7: Model demonstrating the element performance for the operational environment	Performance is demonstrated for the operational environment, on the ground or if necessary in space. A representative model, fully reflecting all aspects of the flight model design, is built and tested with adequate margins for demonstrating the performance in the operational environment.	Definition of performance requirements, including definition of the operational environment. Model definition and realization. Model test plan. Model test results.
TRL 8: Actual system completed and accepted for flight ("flight qualified")	Flight model is qualified and integrated in the final system ready for flight.	Flight model is built and integrated into the final system. Flight acceptance of the final system.
TRL 9: Actual system "flight proven" through successful mission operations	Technology is mature. The element is successfully in service for the assigned mission in the actual operational environment.	Commissioning in early operation phase. In-orbit operation report.

Launchers for M5

- Considering M5 launch date, baseline is to consider European new launcher family (Vega-C or Ariane 6)
- Non-European launchers possible in the context of international collaboration
    - Partner provision, thus requiring confirmation
    - Launch from China requires careful consideration due to Export Control regulations
- Launcher costs current best estimates:

  Vega-C (*): 38 M€

  Ariane 6.2/6.4(*): 70 M€/TBD M€

  (*) cost targets based on launcher market projections. Actual costs for M5 could change with the market evolution.

New launcher family capabilities

The new launcher family is still in the design phase: PDR is planned mid-2016.

Maiden flights: Vega-C by 2018, Ariane 6 by 2020. Therefore, actual performance will be progressively consolidated!

Overall, generally equal or better performance requirements w.r.t. previous family VEGA/SOYUZ/A5-ECA

Preliminary targeted capabilities:

VEGA-C: typ. + 20% vs VEGA, ~ 1800 kg @ 700 km/polar

Ariane 6.2: typ. +50% vs Soyuz-F to GTO (~ 5 t); L2 ~ 3 t

Ariane 6.4: slightly better than A5-ECA to GTO, 10.5 t; L2 ~ 6.6 t

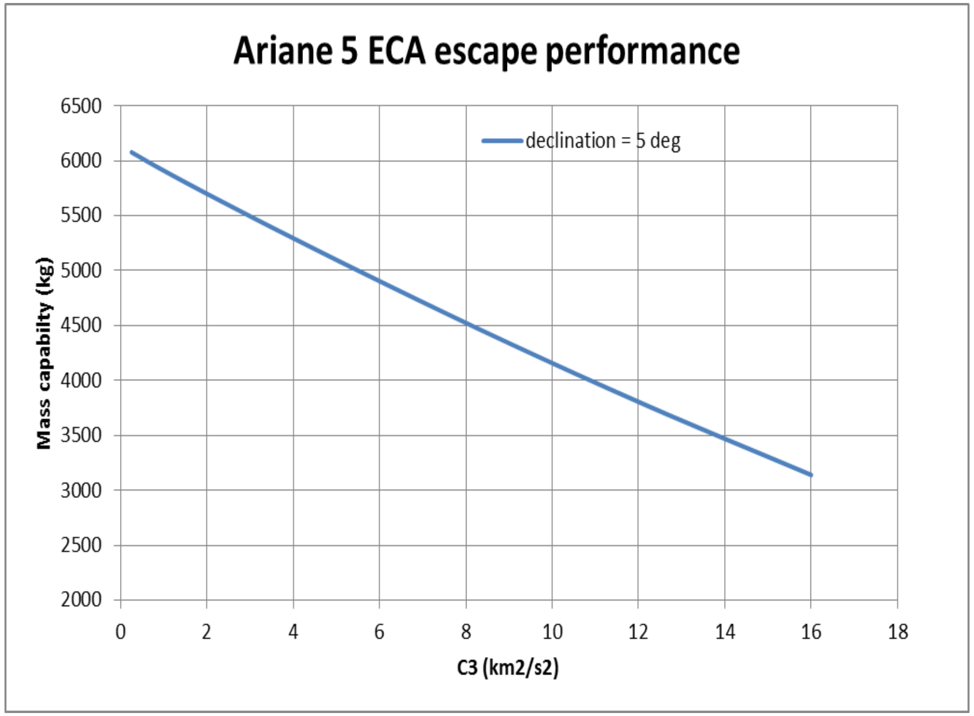
Important note: The above figures include the launch adapter. Considering the launchers are still in the design phase, figures can still evolve!

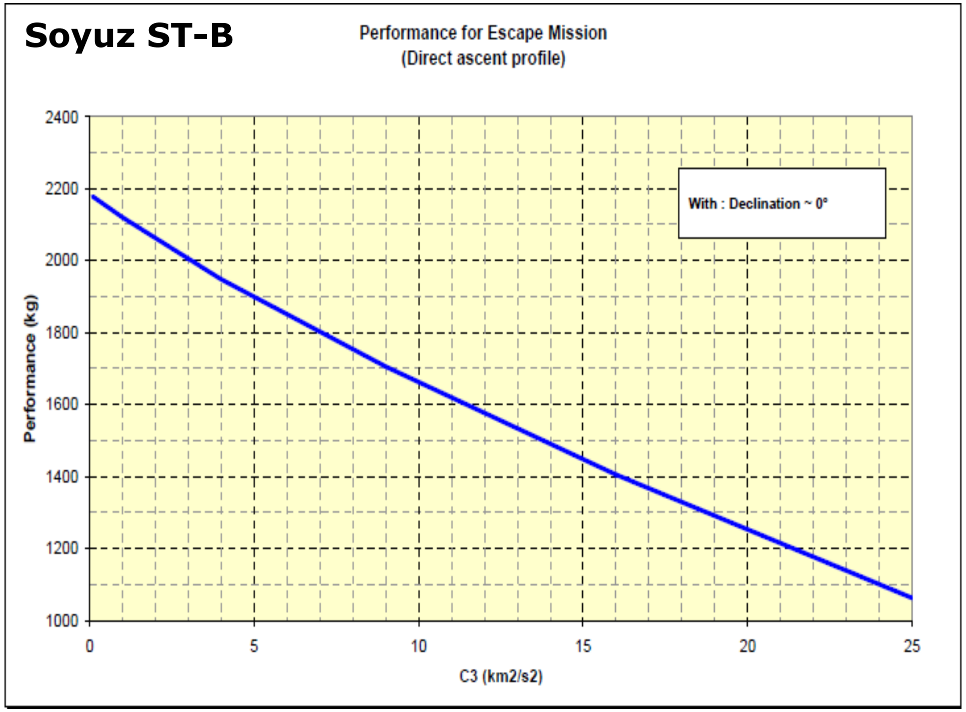
Users Manual expected Q1 2016.

Ariane 6 escape performance

- Mass Performance of Ariane 62 and Ariane 64 into escape trajectories are not available yet. Soyuz and Ariane 5 ECA performance is given as reference below.

  Note: $C3 = V(\infty)^2$





ESA Ground Stations

ESA's tracking station network – Estrack – is a global system of ground stations comprising 10 stations in seven countries.

Estrack includes 3 high performance *Deep Space Antennas* (35 m diameter) that are of particular relevance to science missions. The DSAs operate in X band for uplink and X/Ka bands for downlink.

DSA-1 is in New Norcia, Australia;

DSA-2 is in Cebreros, Spain;

DSA-3 is in Malargüe, Argentina;

35 m antenna in New Norcia

"Typical" downlink data rates (during station visibility)

Orbit	Downlink rate	Note
LEO	X-band: up to 10 Mbps S-band: up to 1 Mbps	Limited by regulations on max bandwidth for Science Missions S-band not recommended due to likely future restrictions
HEO	X-band: up to 10 Mbps	Limited by regulations on max bandwidth for Science Missions
L1/L2	X-band: up to 10 Mbps K-band (25.5-27 GHz): up to 75 Mbps	X-band Limited by regulations on max bandwidth for Science Missions K-band: ref. Euclid (Antenna A =0.4 m, P=51 W)
@ Mercury	Ka-band (31.8-32.3 GHz): ~100 kbps X-band : ~ 50 kbps	Depending on onboard power and antenna size. Ref. BepiColombo (A=1.1 m, P=80 W)
@ Venus	X-band: between ~15-200 kbps	Depending on onboard power and antenna size. Ref. VEX (A=1.3 m, P= 70 W)
@ Mars	X-band: between ~30-230 kbps	Depending on onboard power and antenna size. Ref. TGO (A=2.2 m, P=65 W)
@Jupiter	X-band: ~50 kbps Ka-band: ~120 kbps	Depending on onboard power and antenna size. Ref. JUICE (A=3 m, P= 60 W)

Generic questions not covered by preceding slides (1)

Q: Can ESA help the team during the proposal phase? (e.g. mission analysis, costing, concept of operations etc)

A: No, would be impossible to handle in practice while preserving fair competition

Q: Can the mission rely on European RTGs/RHUs?

A: No, there is no European program to develop Nuclear Power Systems on a schedule compatible with M5

Q: Can we envisage spacecraft operations under ESA contract by another European organization?

A: ESA-funded spacecraft operations are done by ESA/ESOC.

Generic questions not covered by preceding slides (2)

Q: Any concern on using spacecraft (platform) components for science purpose?

A: No a priori concern, if use as is and compatible with the spacecraft operation needs. To be addressed on case by case basis.

Q: How is the cost estimation of the spacecraft performed: by similarity to other missions, parametric or bottom-up?

A: All…Bottom-up is always independently assessed by ESA, with increasing level of confidence through phases (Phase 0/A/B1), by relying on ESA parametric database. Bottom-up is also always requested from industry in both Phases A/B1. Benchmarking with previous missions is also systematically achieved, at all levels. The contingency is generally sized to the mission specific needs.

Generic questions not covered by preceding slides (3)

Q: Can the proposers provide detailed assessment reports in addition to the proposal

A: The proposal evaluation solely relies on the mission proposal, which must be self-contained and include all critical elements for enabling a sound assessment, while strictly complying with the required number of pages. The proposers are free to add links in their proposal, referring to detailed documents. ESA may (or not) consider them as background information for the evaluation.

Generic questions not covered by preceding slides (4)

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Q: Can ESA further provide a breakdown for operational costs e.g. for commissioning, cruise, science operations, etc

A: No generic figures can be provided since the concept of operations is mission dependent. MOC/SOC costs are reduced through routine operations, involving minimum modes and human intervention. The above mentioned figure (15% of CaC) is a reasonable estimate assuming no exotic operation concepts. In general, operation costs are not expected to be a strong discriminant for the proposal selection.

Planetary missions with long cruise phase generally feature higher MOC costs, but are often less demanding for Science Operations. As illustrative example, for M3 candidates, the overall operations costs (MOC + SOC) were very similar for MarcoPolo-R, ECHO and LOFT with a different distribution between MOC and SOC, and slightly higher for PLATO (~20%) partly because of longer operations (6 years).

Generic questions not covered by preceding slides (5)

Q: Are there guidelines for geo-return constraints?

A: These are not to be considered by proposers. It is recommended the proposers should not critically base their proposal on recurring costs from previous missions, since ESA estimate will include non-recurring costs for at least two reasons: 1) New science missions anyhow require non-recurring developments for both the S/C and the Payload (e.g. simply due to the development time scale and obsolescence) and 2) the industrial distribution assumptions underlying recurring costs can be incompatible with the Programme needs.

The end