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MOON 2020-2030
A new era of human and robotic exploration

BB1: TELE-ROBOTIC AND AUTONOMOUS CONTROL SYSTEMS

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ESA/ESTEC Noordwijk
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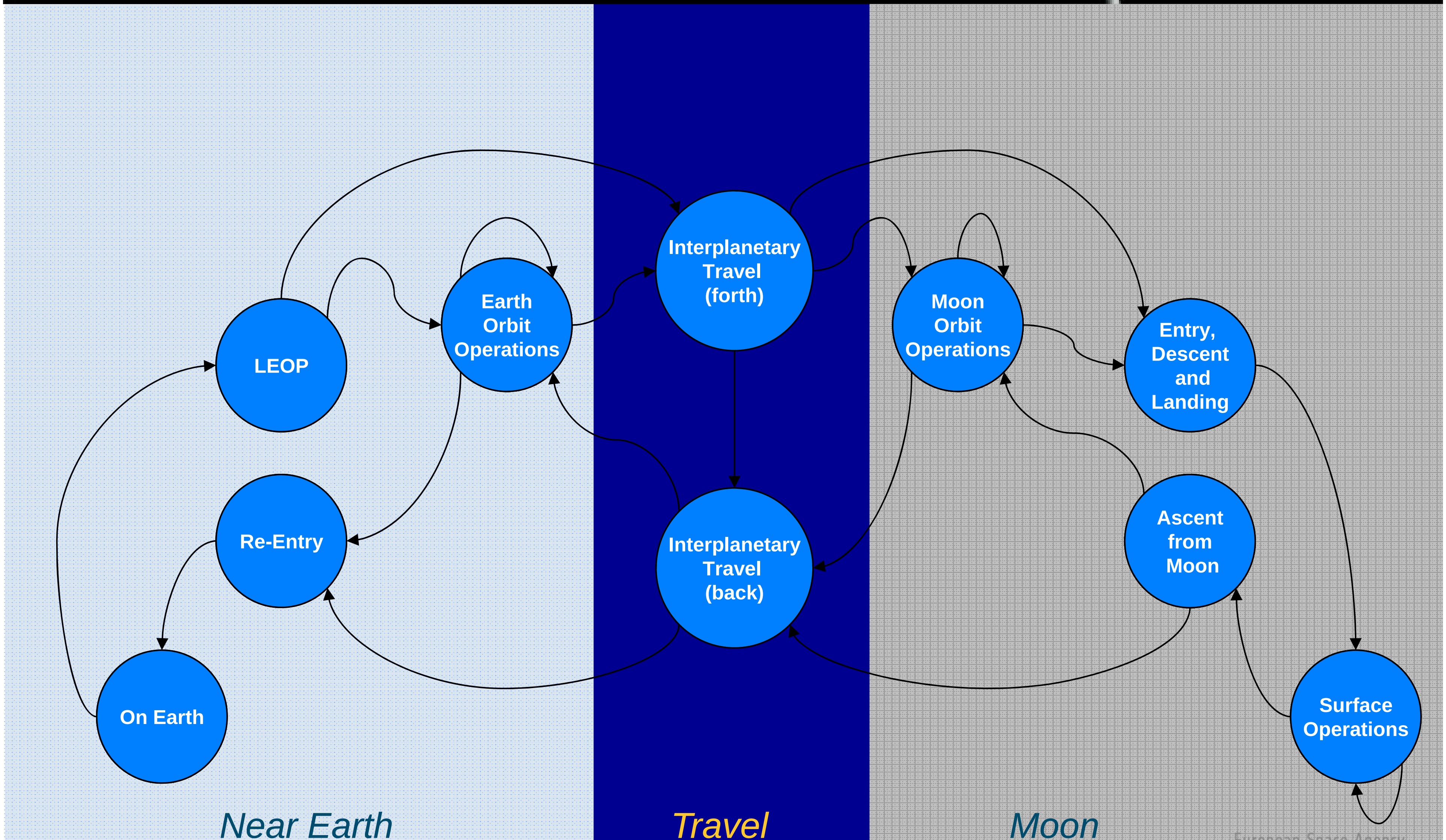
European Space Agency

GENERIC MODEL OF A MISSION TO THE MOON

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LEOP
Earth Orbit Operations
Interplanetary Travel (forth)
Moon Orbit Operations
Entry, Descent and Landing
Re-Entry
Interplanetary Travel (back)
Ascent from Moon
On Earth
Surface Operations

GNC for re-fuelling

Control of compound of chaser and refuelling mechanism. Arrival in the vicinity of the target, extension of the refuelling mechanism and control of the relative distance between both vehicles. The development of the refuelling mechanism is not accounted for here but in the robotics roadmap

GNC for manned missions

GNC with Man In the Loop (MIL) capabilities. Manmachine interaction with GNC systems. Control and Command of vehicles using joysticks, panels, buttons, displays, visual cues, etc. Also applicable to active debris removal. Astronaut or ground controller.

Image processing and pose estimation

Image processing (2D and 3D) of targets for both uncooperative rendezvous and refuelling missions. Images can be obtained via several sensors in visible, infrared, or ultraviolet wavelengths. Processing is performed on board using a dedicated DSP computer

Onboard realtime pose estimation to obtain relative position and attitude of target for both uncooperative and refuelling missions. Pose estimation is computed onboard and in real time by the onboard computer

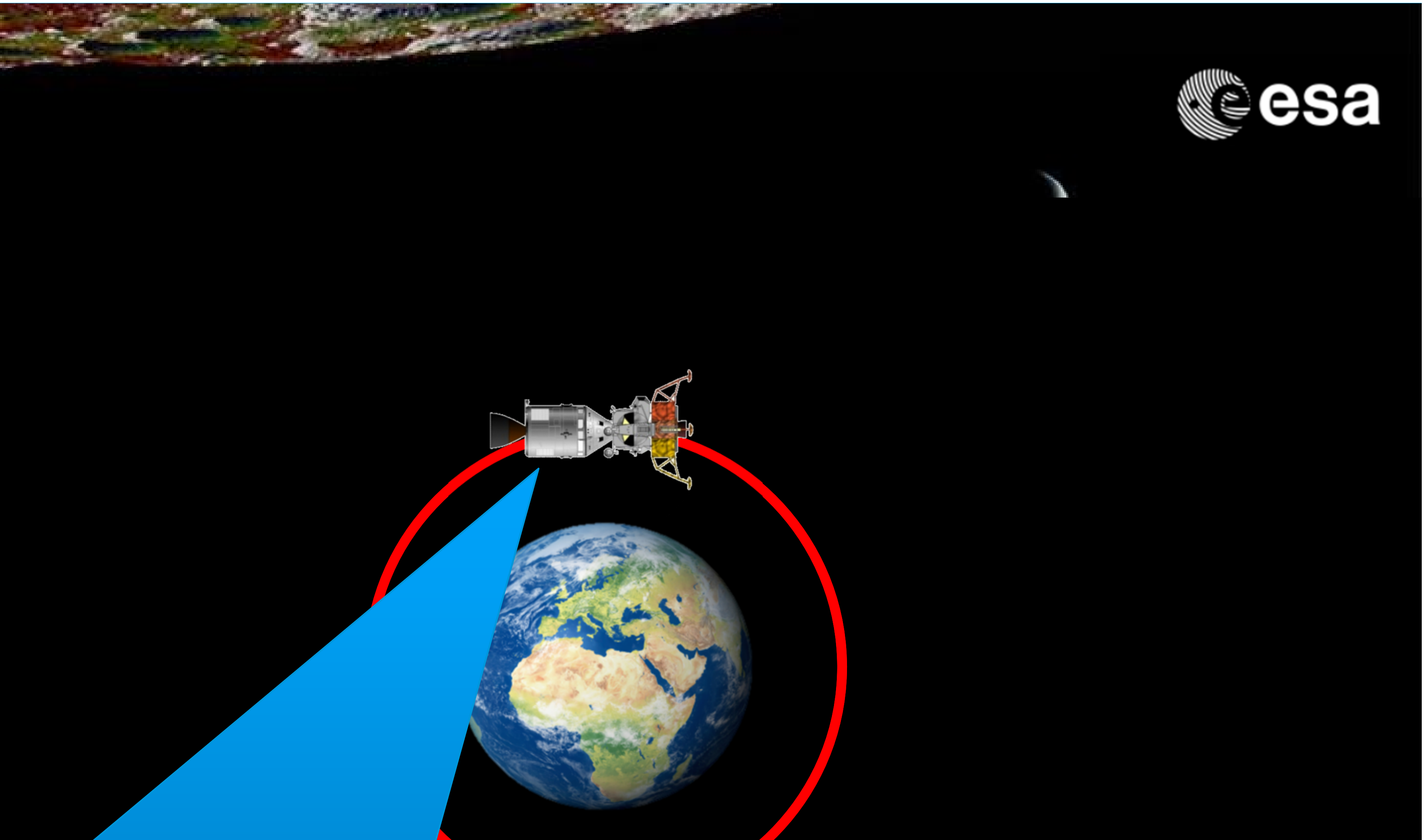
Navigation for manned systems

drive the design of the LIRIS sensors and their expected behaviour in flight;

improve the navigation algorithms that can use the data provided by the sensors, derive realistic specification in terms of expected performance and address the need toward processing speed for on-board avionics that will also be critical for vision based 6DoF nav.

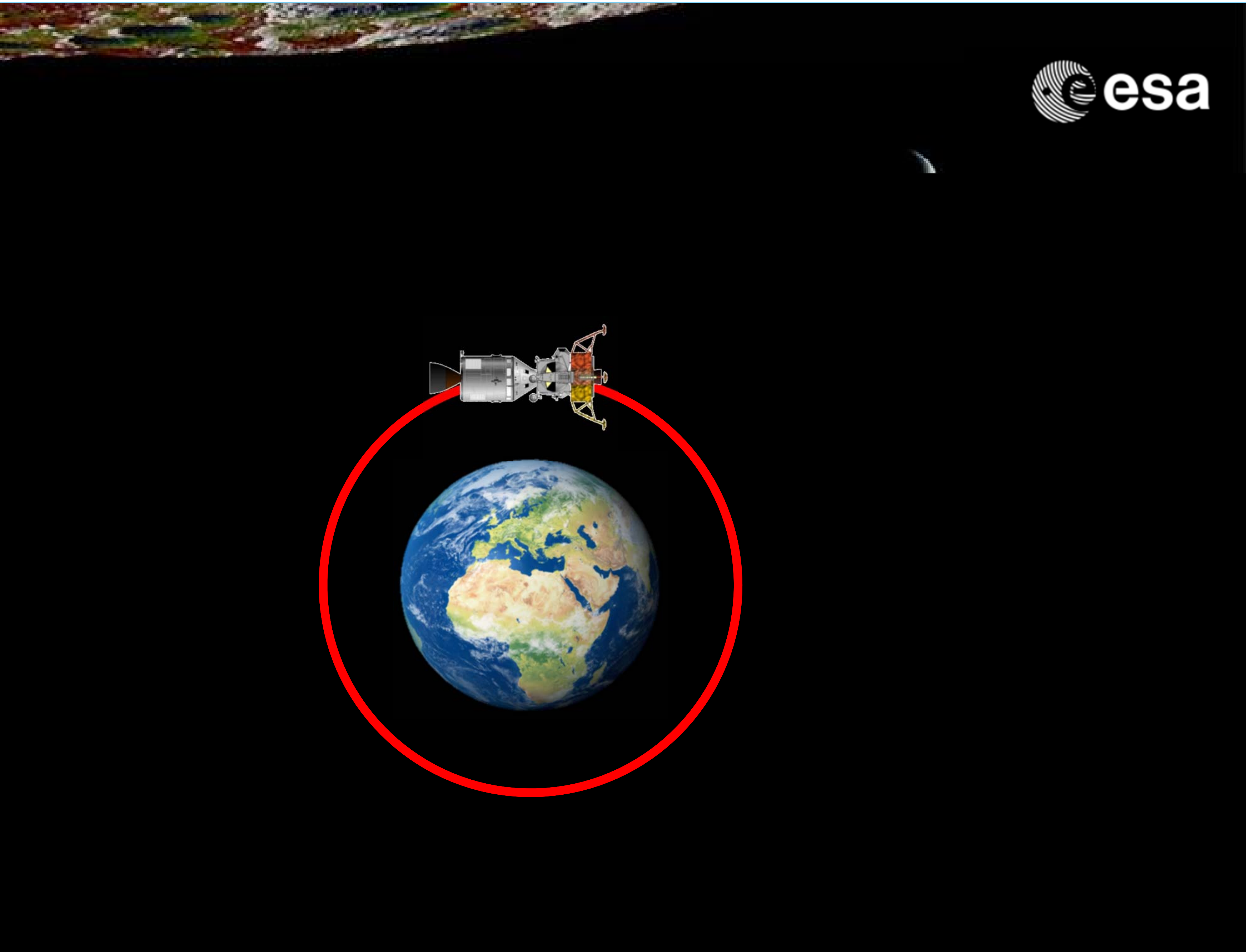
develop an in-the-loop navigation system, including flight avionics

develop and validate LIRIS derived Navigation sensors and algorithms for future application in manned RdV scenarios (MPCV RdV experiment)



ol of large vehicles

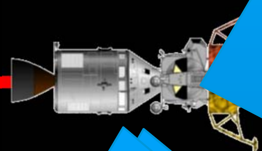
sciplinary design and development of GNC for large vehicles.
ced and modern control of servicing vehicles with large solar
, large antennas, appendages. Use of CMGs.



GNC for autonomous and agile systems

Advanced GNC with intelligence to increase autonomy including complex mission vehicle management functions.

Specially for interplanetary missions where ground contact is not an option to execute maneuvers with accuracy and robustness



Tolerant syste

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capability to ac
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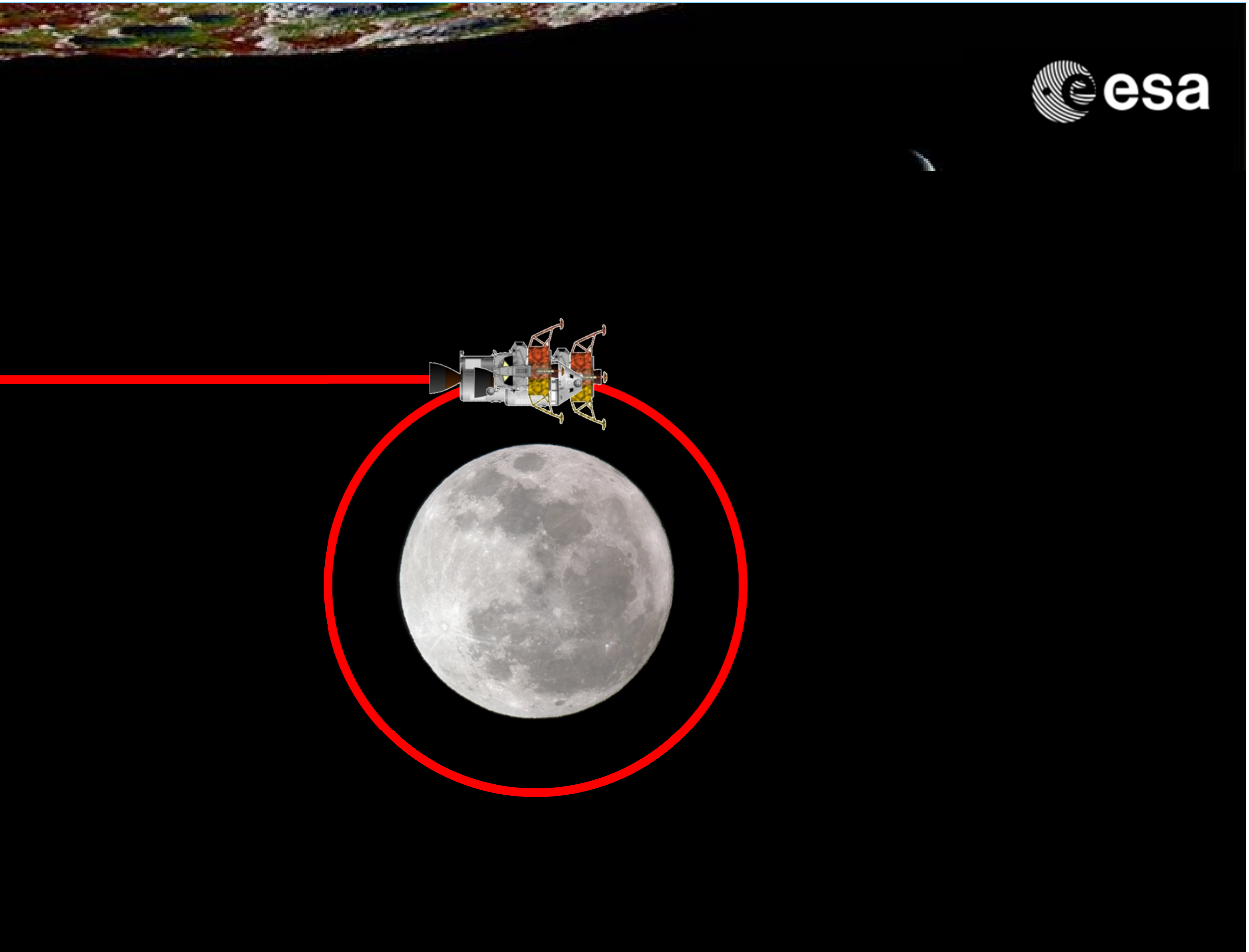
Regenerative (High Temperature PEM) fuel cell

RFCs have the potential of a huge step in specific energy at the expense of a complexity that is much larger than this of batteries

As a consequence they can be competitive (or even enabling) only for very high levels of stored energy, like what can be expected for human exploration.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cell efficiency (conservative funding)

nt State of the art is 30% Beginning of Life (BoL)
ponding technology (triple junction / lattice matched) will not
further progress
echnologies and possibly new manufacturing processes are to be
d to secure European position at the forefront
rvative funding , i.e. more or less the same level of yearly
ng as for the current generation will make 33% efficient cell ready
alification by 2016 and 35% by 2019.

specific energy Li ion cell (> 250 Wh/kg)

photovoltaics the increase of specific energy, allowing mass
nment for very high power missions, is a permanent goal The State of
t Lithium-ion has still some growth capability but a breakthrough will
ded to further progress

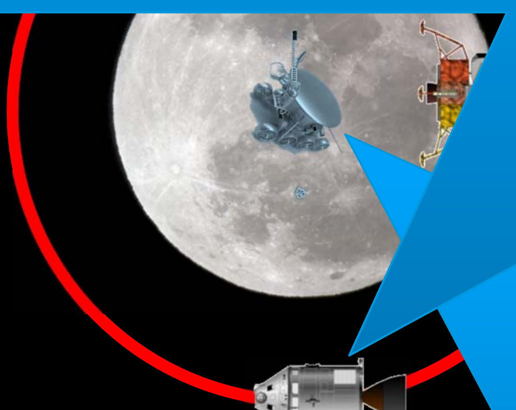
specific energy Li ion cell at low temperature (<-20C)

ermal control of planetary surface systems (e.g. rovers) is
ed both by the limited amount of energy available for heating in
onditions and by the long duration of nights
ttery is among the equipment the most sensitive to low
rature and Liion has very poor charging capabilities in such
ons, making the energy balance even more difficult to achieve
ore a Liion cell operating at low temperature would bring very
cant benefits to the energy balance of planetary systems.

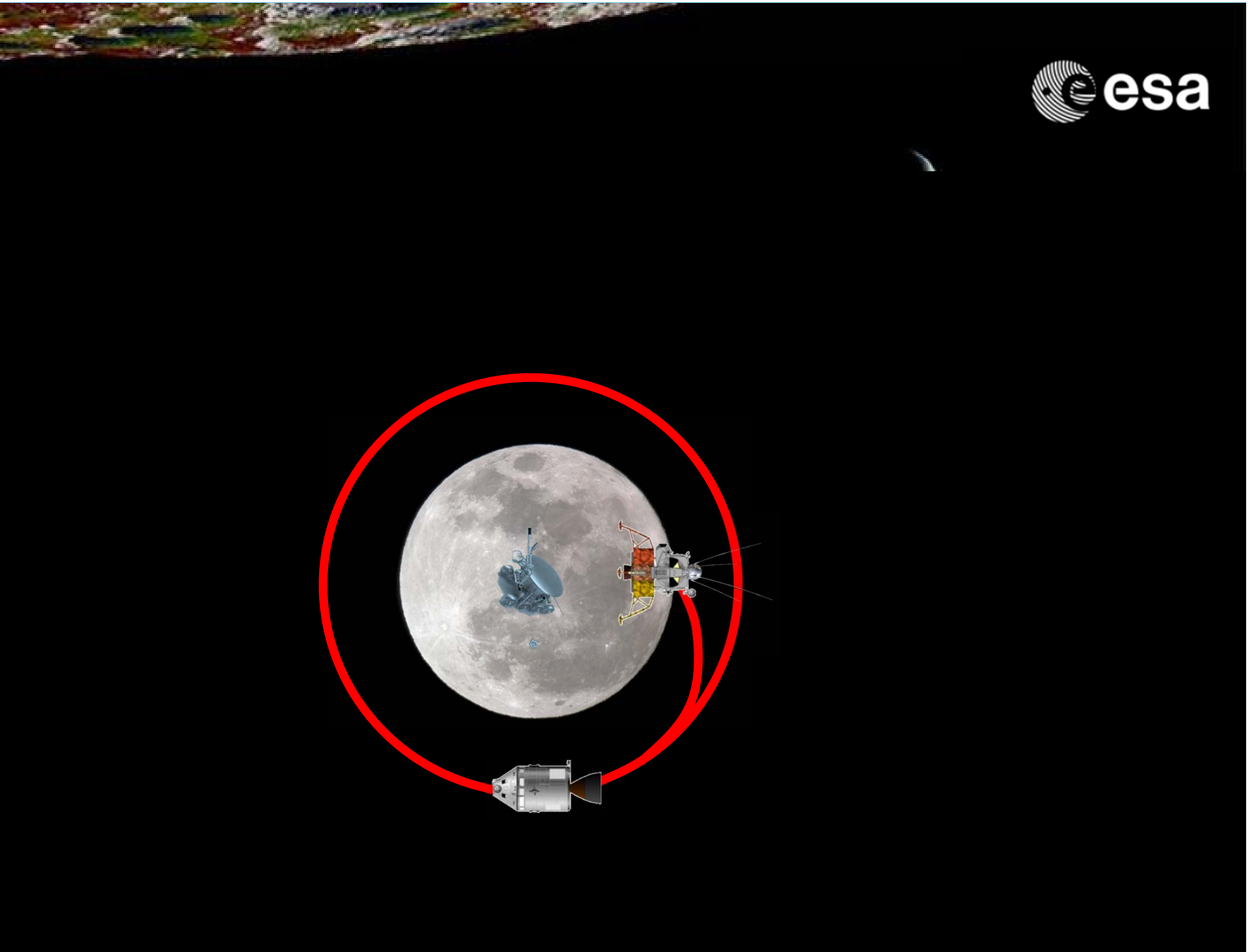
turised antennas for RF tracking of probes

na system with simplified switching capabilities for probes, cubesats,
anders etc. In conjunction with radiolinks present.
expected TRL5 in 2020

ERON The activities in this line aim at developing and demonstrating
nced haptic teleoperation technology that will allow intuitive and
ive teleoperation of humanoid robots with typical orbit <-> ground
nunication. Costs indicated for the project include 30% margins.
-autonomous-robot collaborative activities are not addressed at the
ent as the robots are considered to be teleoperated/pre-programmed.
aptic technology pursued will allow to operate the proposed HSO
ic EVA assistant and it has been also proposed
uclear handling



rate localisation of assets on planets
transfer to landers using two way link to synchronise local clock(s)
hase transfer link. Local redistribution of locked signals to provide
le beacon scenario in case of need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imal ascent trajectories
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orbiter. Optimal trajectories
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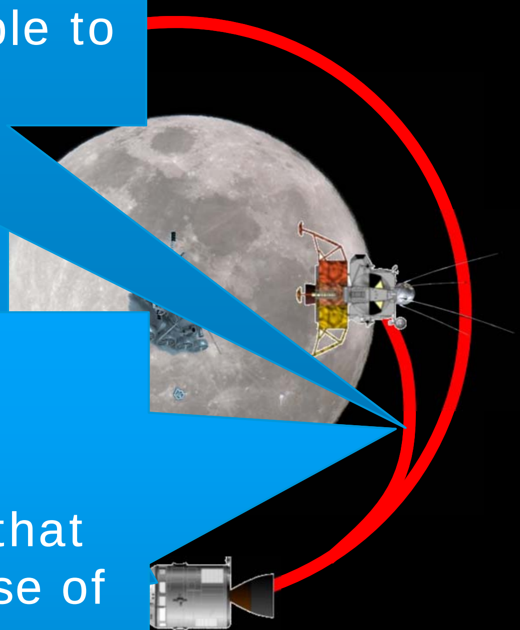


ti-disciplinary design
imization
D for the design and the
elopment of the rocket that
ains the sample. The use of
current engineering
niques for the design of the
ket, including GNC, aero,
pulsion, stating, mass

GH PERFORMANCE INTEGRATED AVIONICS

n performance computers

- ligh throughput COTS computers protected against radiation effects through uplication or triplication with master or voting mechanism,
- Jse of multi-core (NGMP) or many-core (LEON3 + specialized processors).
- Beyond the microelectronic manufacturing and cost challenge, an appropriate oftware architecture is needed to benefit from the hardware throughput vithout suffering from classical slow-down effects such as bus contentions.

onics architecture for adaptive applications

- he need for the system to adapt to unexpected environment impacts on
- lardware architecture e.g. by use of reconfigurable FPGAs
- oftware architecture by use of on-board prognosis to verify the plan enerated by the on-board planner and ask for re-plan if necessary

C verification & validation facilities

- Jpdate, extension and maintenance of the PLATFORM facility at INTA (Madrid, Spain Extension of length of the facility. Update to noncooperative targets. Jpdate of the lighting conditions. Command from remote locations. Update vith canister capabilities
- Jpdate, extension and maintenance of the EPOS facility at DLR (Munich, Germany. Update of the dynamics system of the facility. Update the facility vith contact dynamics capabilities and robotic arms in the loop, test of net nd tentacles systems
- Jpdate, extension and maintenance of the EPOSx facility in DGA (Paris, rance). Maintenance of the facility.

GINEERING PROCESSES AND SUPPORTING OLS

el-based SW Engineering

To reduce the test effort of complex software, model based verification at esign level requires sound architecture (“correct by construction) based on separation of concern” principle, supported by appropriate tools to verify oftware & system properties

he software development is model-centric. The software models are derived rom system models such as (i) requirements models in SysML or equirements ontologies allowing verification of requirements, (ii) ependability models allowing the verification of the FDIR component, (iii) IW-SW models allowing to trade-off implementation in software or in nicroelectronic, (iv) data models implemented in the System Data Repository.

he software models include in addition an architectural model allowing erification of real-time properties, allowing interoperability of components, llowing reuse based on variability points, and functional models allowing ehavioural verification.

Software factory takes in input all these models and assemble, generates nd configure the code of the on-board software

E VERIFICATION OF HIGHLY ADAPTIVE
STEMS

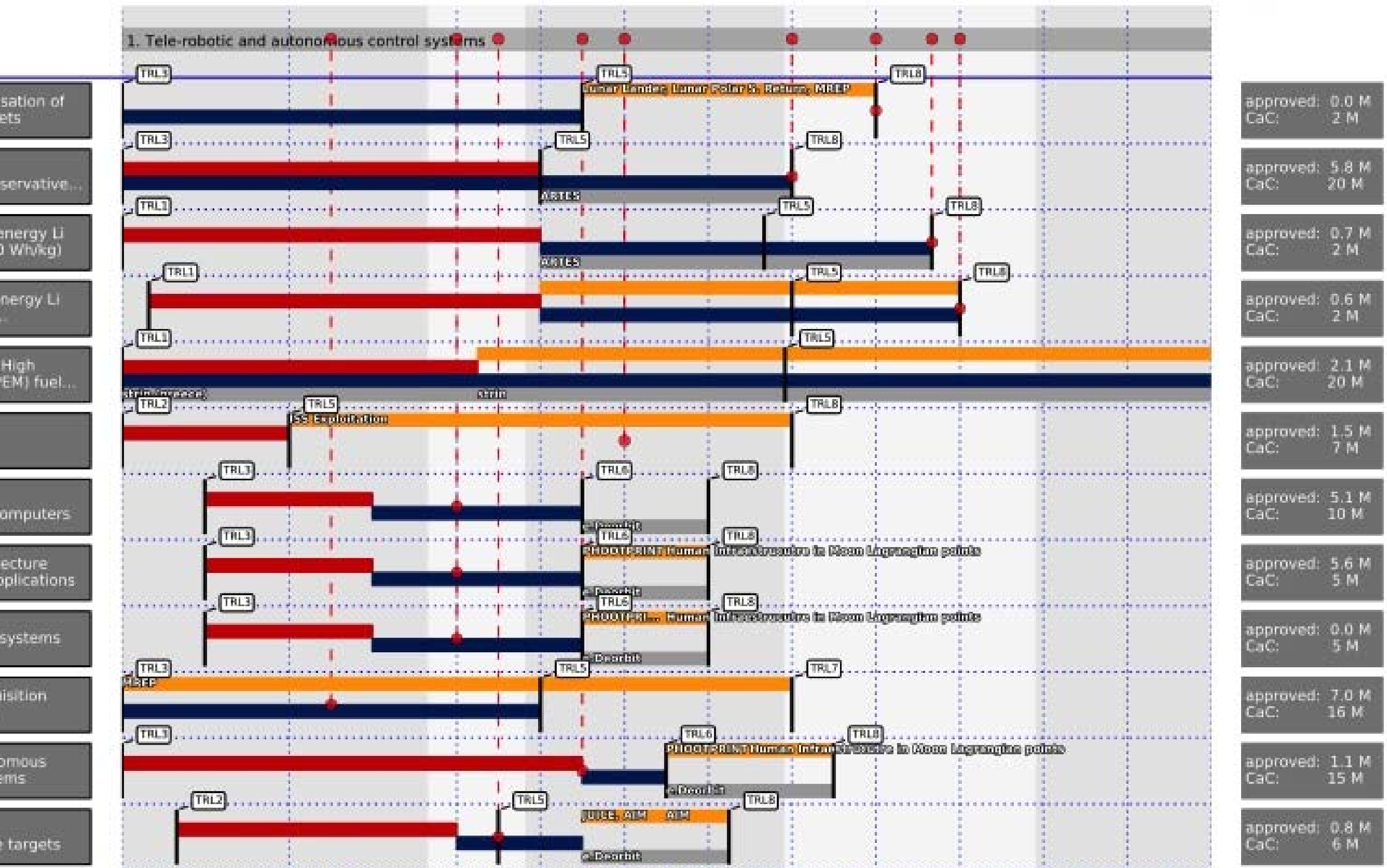
Verification of Highly adaptive Systems

rameworks need to be developed to support the end-to-end verification of ighly adaptive systems. Specific methods for fault management, fault olerant systems and highly autonomous systems need to be consolidated.

Dedicated testbenches need to be developed and configured for the specific nissions and made available for all partners in collaborations.


THANK YOU

E ROADMAP FOR BB1



E ROADMAP FOR BB1