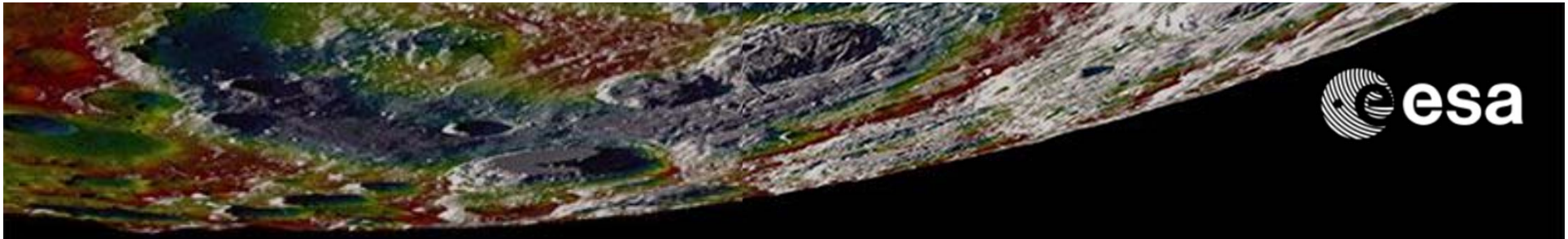

MOON 2020-2030
A new era of human and robotic exploration

BB5 SURFACE MOBILITY ELEMENTS

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ESA/ESTEC Noordwijk
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European Space Agency

MAIN REQUIREMENTS AND CHALLENGES

- Surface mobility means the capability to move rovers, manned or not, across the Moon surface, for durations from hours to months
- The main challenge is of course for manned system, for which a typical mass range is from 500 kg to several metric tons
- The associated challenges, as illustrated by the BB5 road maps, are mostly:
  - Mechanisms: high power/high torque electrical motors
  - the level of requested power and energy
    - from a few to tens of kW and from a few to hundreds of kWh
  - the thermal control
    - minimising the need for heating in cold case (night, shadowed relief)
    - while ensuring the proper rejection of thermal power in the hot one
  - navigation
    - inertial methods usable for short trips
    - need to be complemented by absolute position determination
  - communications
    - need to maintain a permanent link

MAIN CGALLENGES: ELECTGRICAL ACTUATORS

- Rotary Actuator in Harsh Environment (RAHE) as a generic input :
  - TRP RAHE (on going) but limited to 45 N.m is typically using a 2-stage gearbox (planetary stage & Harmonic Drive)
  - For instance, the NASA Tri-Athlete foresees torques up to 10.000 N.m in cryo-temperature,
  - Active thermal control to avoid dry lubrication is highly desirable but call for higher power demand.

MAIN CHALLENGES : POWER

- No readily available power sources

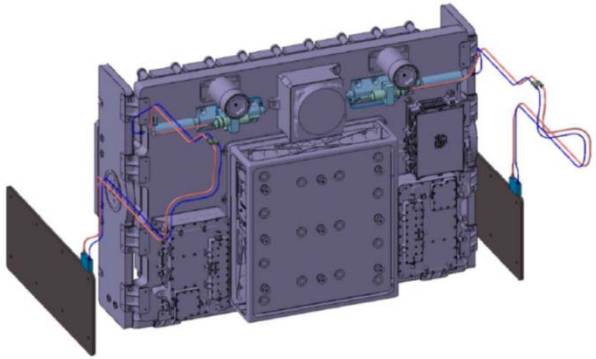
- Most common primary power sources not fit for the job:
  - Solar generator not usable for large rovers
    - power per unit area too low w.r.t. available surface (think of solar powered aircraft as Solar Impulse 2)
    - sun angle not always favourable, dust deposition
  - Radioisotopic Thermal Generators offer low power
    - suitable for an automated rover, e.g. Curiosity
      - current developments ongoing in Europe with Am241 as isotope
    - but daily energy production far from what is required for a manned rover

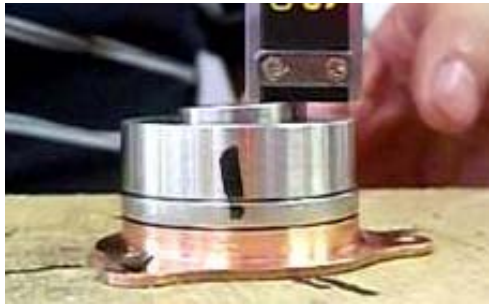
MAIN CHALLENGES : POWER

- Secondary sources are needed to accumulate energy and/or provide peak power
  - Best (terrestrial) cells are beyond 250Wh/kg.
    - 100 kwh means 400 kg
    - but represents only a few hours of driving
    - without even considering the needs of LSS and thermal
  - and fuel cells may not be the solution either
    - energy density will stay far from theoretical as long as hydrogen storage issues are not solved
- Nuclear reactor is the best choice on paper
  - power capability from 10 kw to MW
  - independent from external conditions
  - waste heat usable for thermal control
  - BUT safety issues and high price tag.

MAIN CHALLENGES : THERMAL

- Surface mobility elements major thermal design drivers:
  - Large temperature excursion over a long lunar day
  - Large power variations of electronic units used for the surface mobility
  - Limited power generation requires efficient thermal control with minimal heater power
- Loop Heat Pipe (LHP) based heat switch developed in a TRP and currently being qualified in Exomars
  - Current heat rejection from 10W to 100W Could be extended up to 1KW combined with the combination of the compact radiator louver or variable emissivity coatings (note: would also require to address dust related issues)
- Mechanical Heat Switch for small point source temperature control, e.g. navigation cameras
  - On-Going TRP, TRL 4 in 4Q 2016. Heat rejection from 1W to 10W



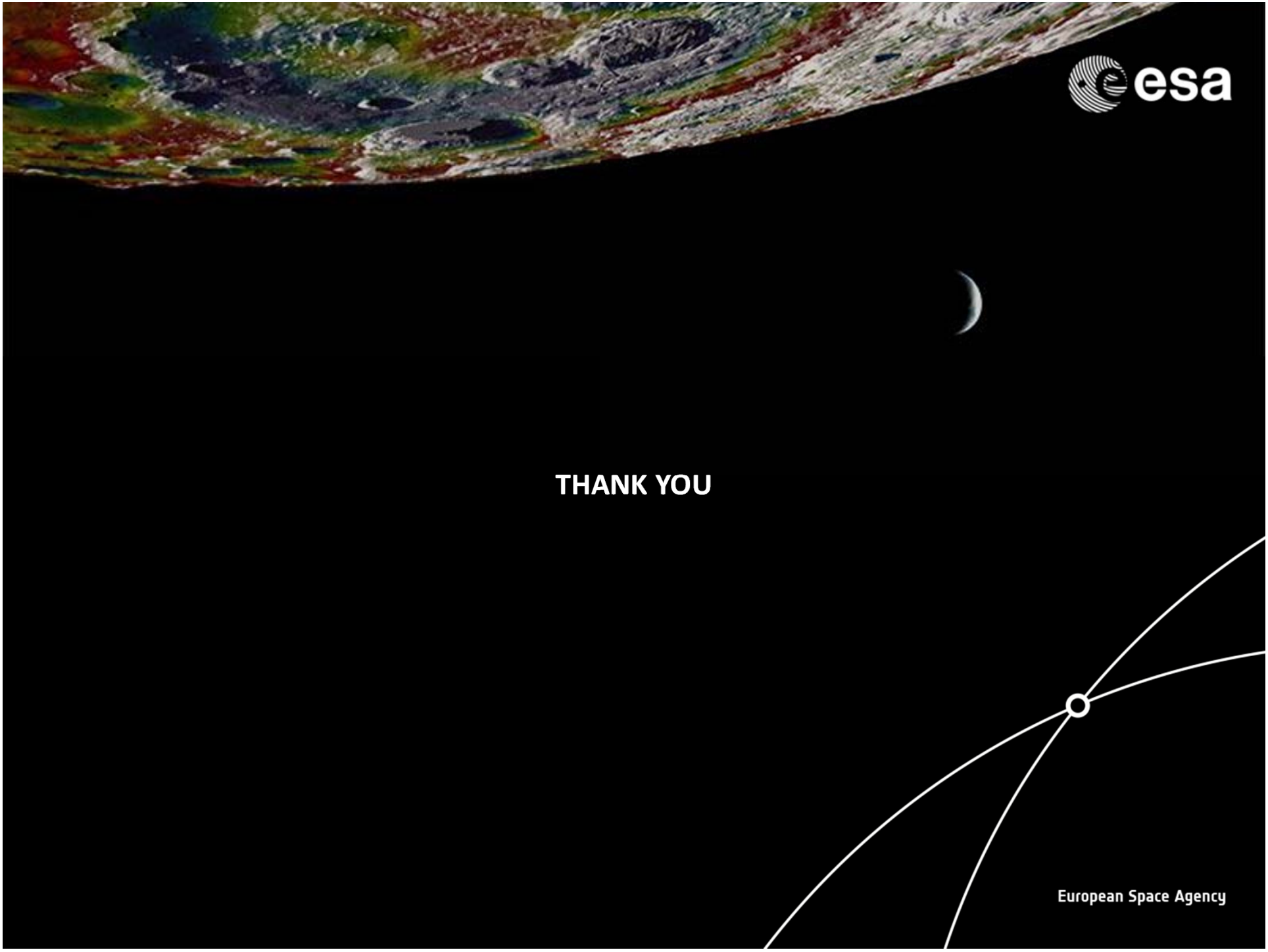


MAIN CHALLENGES : COMMUNICATIONS

- **Miniaturised antennas for on-surface planetary communication**
  - Although several frequencies are under consideration for communications on Lunar missions, independently of the selection, the allocated real estate will be very small and every effort should be made to miniaturise the antennas.
  - TRL 4; expected TRL 6 in 2018
- **Antenna cluster for planetary communication**
  - Planetary exploration with nodes scattered across the surface will require on-surface-communication. Different requirements/technologies depending on the distance to the base station. Several “operational scenarios” defined with different data rate requirements.
  - TRL 2; expected TRL 5 in 2020

MAIN CHALLENGES : NAVIGATION

- **Near Real Time VLBI tracking of assets**
  - Cooperation with European VLBI Network. High bit-rate interconnect to central correlator, to be adapted for SC tracking. Planetary landers and other interplanetary SC in need for precision/localisation/trajectory and/or timing measurement.
    - TRL 3; expected TRL 5 in 2019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THANK YOU
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