



MOON 2020-2030

A new era of human and robotic exploration

USE OF ESA EXPLORATION TECHNOLOGY ROADMAPS IN SUPPORT OF MOON INITIATIVES AND TECHNOLOGY PRIORITISATION

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European Space Agency

(with contribution of the Politecnico of Turin)

ESA/ESTEC Noordwijk

14 December 2015

European Space Agency

CONTENT



Exploration at ESA and the Technology Roadmaps for Exploration

Building Blocks for Moon Missions


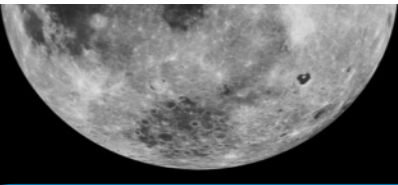
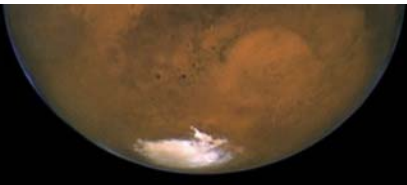
Improving the Technology Roadmaps for Exploration

EXPLORATION AT ESA AND THE TECHNOLOGY ROADMAPS FOR EXPLORATION

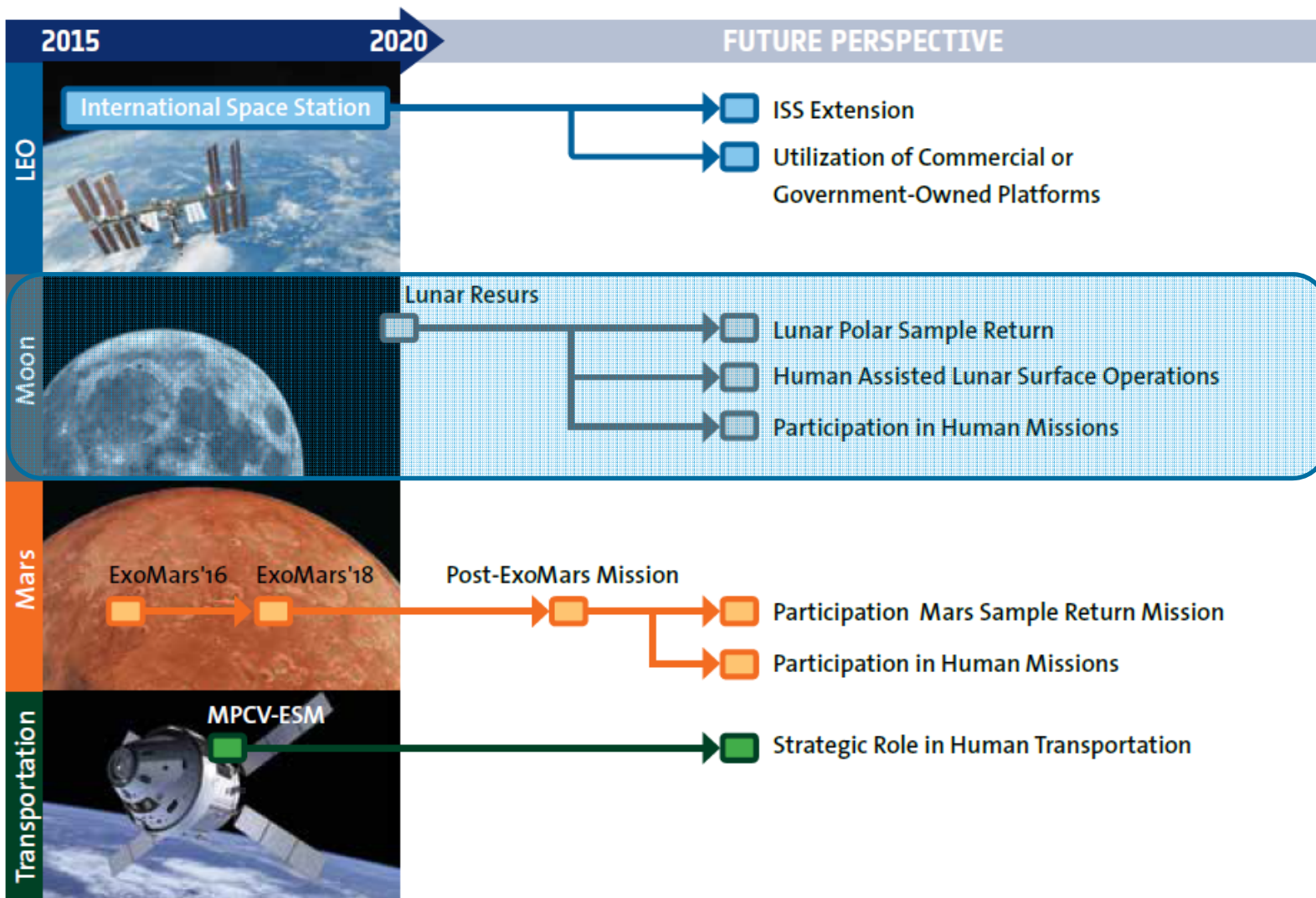


ESA'S EXPLORATION DESTINATION



		
LEO	MOON	MARS
Strategic Aspects		
<ul style="list-style-type: none"> Gradual transition to enlarged roles of private sector 	<ul style="list-style-type: none"> Resource potential 	<ul style="list-style-type: none"> Extension of human activity beyond Earth-Moon system
Science Aspects		
<ul style="list-style-type: none"> Human-assisted research in life and physical sciences Opportunistic science and applications 	<ul style="list-style-type: none"> History of solar system Origin of life on Earth Opportunistic science and applications 	<ul style="list-style-type: none"> Search for life Planetary evolution Opportunistic science and applications
Programmatic Aspects		
<ul style="list-style-type: none"> Preparation of deep space exploration Prepares European roles 	<ul style="list-style-type: none"> First destination of humans beyond LEO Shapes international roles and partnership 	<ul style="list-style-type: none"> Long term destination for humans
ESA Programmes		
<ul style="list-style-type: none"> ISS up to 2020 Beyond 2020 	<ul style="list-style-type: none"> MPCV-ESM Participation in Russian-led unmanned precursors 	<ul style="list-style-type: none"> ExoMars Mars Robotic Exploration Preparation

ESA EXPLORATION SCENARIOS



COORDINATION OF EXPLORATION ACTIVITIES



DG's vision on Exploration presented to Council in June 2010 stated that *"ESA will optimise its internal and external interactions to provide coordinated and coherent messages on Exploration"*.

Under mandate of the *Directors Committee for Exploration*, in December 2011 an internal process of coordination of on-going and possible future procurement actions on **Technologies for Exploration** was initiated, in order to provide a consistent view to ESA Delegations and a better visibility on the Agency's procurement actions and activities in this field.

The above action translated into:

- The compilation of **technology roadmaps**, as a living document, illustrating the technology needed to support space exploration
- The preparation of **co-ordinated procurement plans** for space exploration technologies in Europe, based on these roadmaps

TECHNOLOGY ROADMAPS' GENERATION



Preliminary
Technology
Procurement Plan
preparation:
(8/2012-10/2012)

Ministerial
Conference
2012

Roadmap revision and
Initiation of
technology
procurement
activities
(2013-2015)

2nd
Roadmap
Issued:
(11/2015)

Roadmap preparation:
2nd cycle with industry
(coordinated by
Eurosace) and
Programme Board
Exploration Delegations
involvement
(4/2012-7/2012)

1st Roadmap Issued:
and presentation to
Industrial Policy
Committee and
Exploration Programme
Board
(7/2012-9/2012)

Roadmap
preparation:
1st cycle internal to ESA
and presentation to
Delegations of
Programme Board
Exploration
(12/2011-3/2012)

Coordination
between different
ESA Directorates
involved in Space
Exploration at
Director level

The roadmaps have been cross-checked for consistency with the ones resulting from the ESA Harmonisation Process

CROSSCUTTING
THEME

"Technology
for
Exploration"

ESA Technical
Directorate
Initiative on
"Advancing ESA
Technology
Programmes"

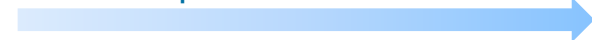
A NEW VERSION OF THE TECHNOLOGY FOR EXPLORATION ROADMAPS



After 2 years since the first edition of the Exploration Technology Roadmaps was prepared and issued, **an update of the Roadmaps** became necessary:

- To support the role of Technology in the **ESA Exploration strategy**
- To reflect a realistic situation in terms of **funding** (the original roadmap was prepared with the intention to reflect, at least for a time span of 3-4 years, a realistic situation in terms of funding available for R&D in this field. The first edition of the Roadmaps was based, among other inputs, on the content of the Programmes as proposed to C-Min 2012 and therefore the status of the technology actions in the Roadmaps needs to be updated following the decisions taken at that Ministerial)
- To adapt the Roadmap's structure to take into account **Future Programmes and Exploration Building Blocks**.

Roadmaps extended to 2030



A NEW VERSION OF THE TECHNOLOGY FOR EXPLORATION ROADMAPS







**Technologies for
Space Exploration
Roadmaps**

**2nd edition
November 2015**





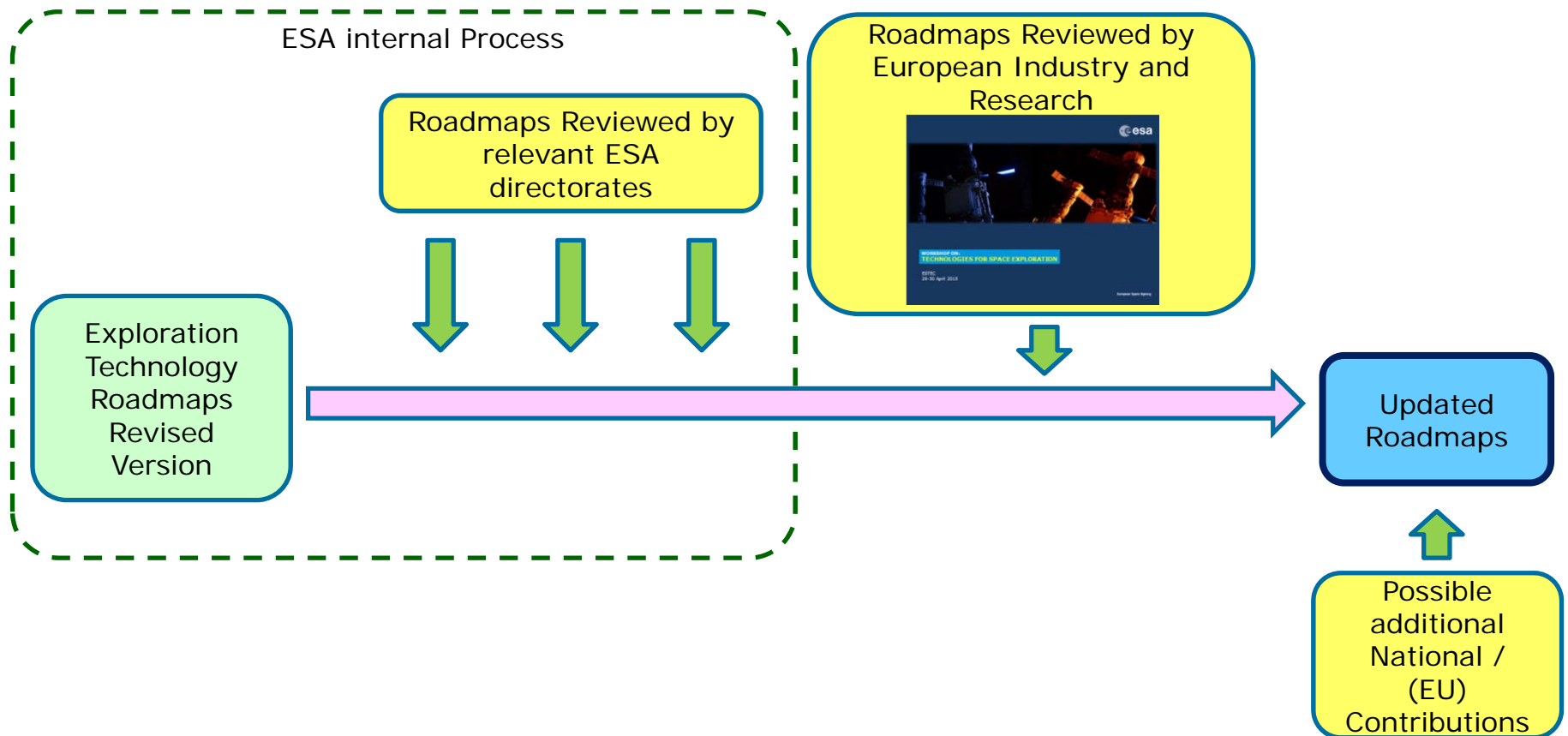
Co-ordinated among:

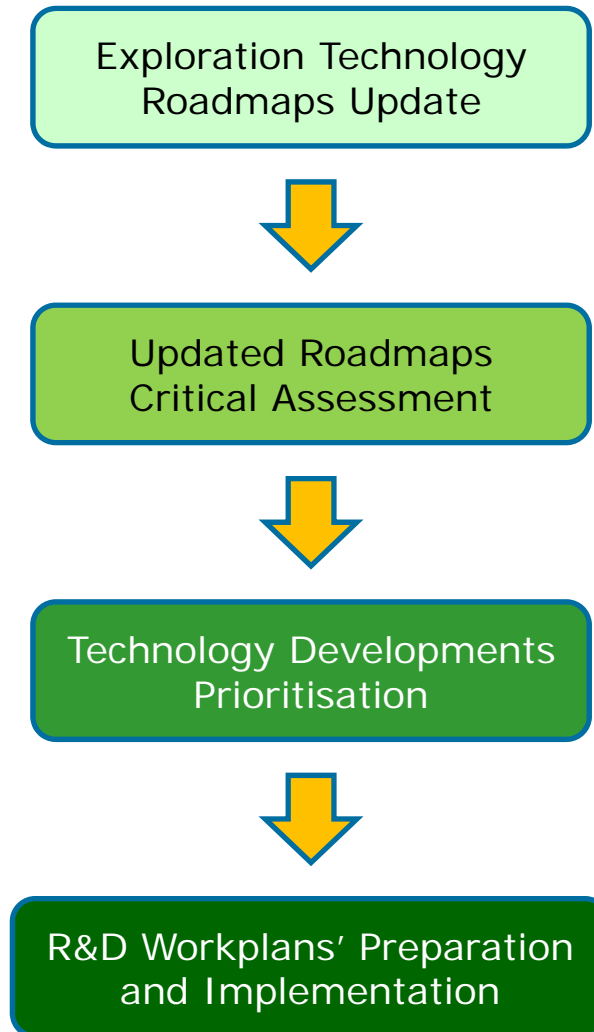
- Technical and Quality Management Directorate (D/TEC)
- Human Spaceflight and Operation Directorate (D/HSO)
- Science and Robotic Exploration Directorate (D/SRE)

Reviewed by European Industry with inputs coordinated by Eurospace

European Space Agency

Roadmaps Review Process Detail

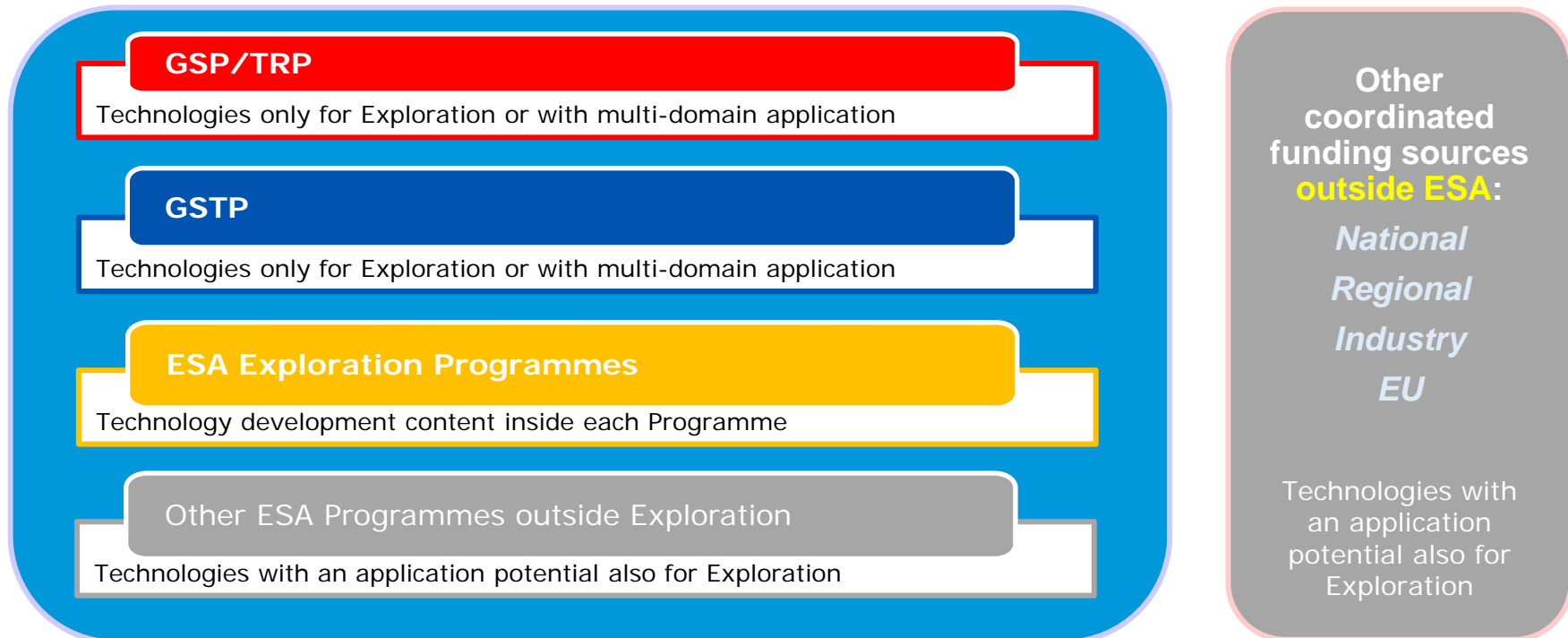




Funding Sources For Exploration Technologies



The technologies presented in the Roadmap and required to engage in an effective Space Exploration programme will be funded through a number of different sources, coordinated in such a way to guarantee timely availability for approved missions and minimisation of procurement risks for technologies with long development time.



Technology Roadmap: Overall Structure



The new roadmaps correlate the following elements:



EXPLORATION TECHNOLOGY APPLICATION AREAS



* Priority Areas for Space Council

THE NEW MISSIONS/PROGRAMMES



LEO Exploitation - permanent station (ISS, post-ISS Station)
LEO Exploitation - Free flyers (e.g. Dragon, Dreamchaser)

Luna-Resurs-Lander

1st MPCV Unmanned Demonstration Mission

2nd MPCV Manned Demonstration Mission

Follow-on MPCV Missions

Lunar Polar Sample Return

Human-robotic Partnership Missions

Extended crew duration missions in cis-lunar space

Human-lunar surface missions

ExoMars 2016

ExoMars 2018

Post ExoMars mission

MSR preparation / MSR elements

Enabling long term technology

THE OPERATIONAL CAPABILITIES



Exploring Space requires the progressive completion of several
“**Incremental Steps**” through the achievement of mandatory
“**Operational Capabilities**” that Europe has to reach alone or in partnership



1. RdV and Docking

2. High Capacity Cargo Transfer

3. Orbit Insertion and Maintenance

4. In-orbit Re-fuelling

5. Sustainable Human Cruise

6. Nuclear Energy Utilisation

7. Entry, Deceleration and Descent

8. Precision Soft Landing

9. Rob/telerob. Surface Operations

10. Surface Habitability and Ops.

11. ISRU

12. Ascent and Return

13. Interoperability

THE BUILDING BLOCKS



Each building block represents an important **capability at mission element**, system or sub-system level and integrates a set of ESA's priority technologies. It represents therefore an area of European industrial expertise.



- Visual navigation, hazard detection and avoidance;
- Sample acquisition, processing and containment system;
- Sample return Earth re-entry capsule;
- Inter-spacecraft communication systems;
- Surface mobility elements;
- Advanced Mars landing systems;
- Miniaturized avionics;
- Planetary protection;
- Tele-robotic and autonomous control systems;
- Rendezvous with non-cooperative targets and docking systems;
- Storable propulsion modules and equipment;
- Habitation systems;
- Ground segment elements.

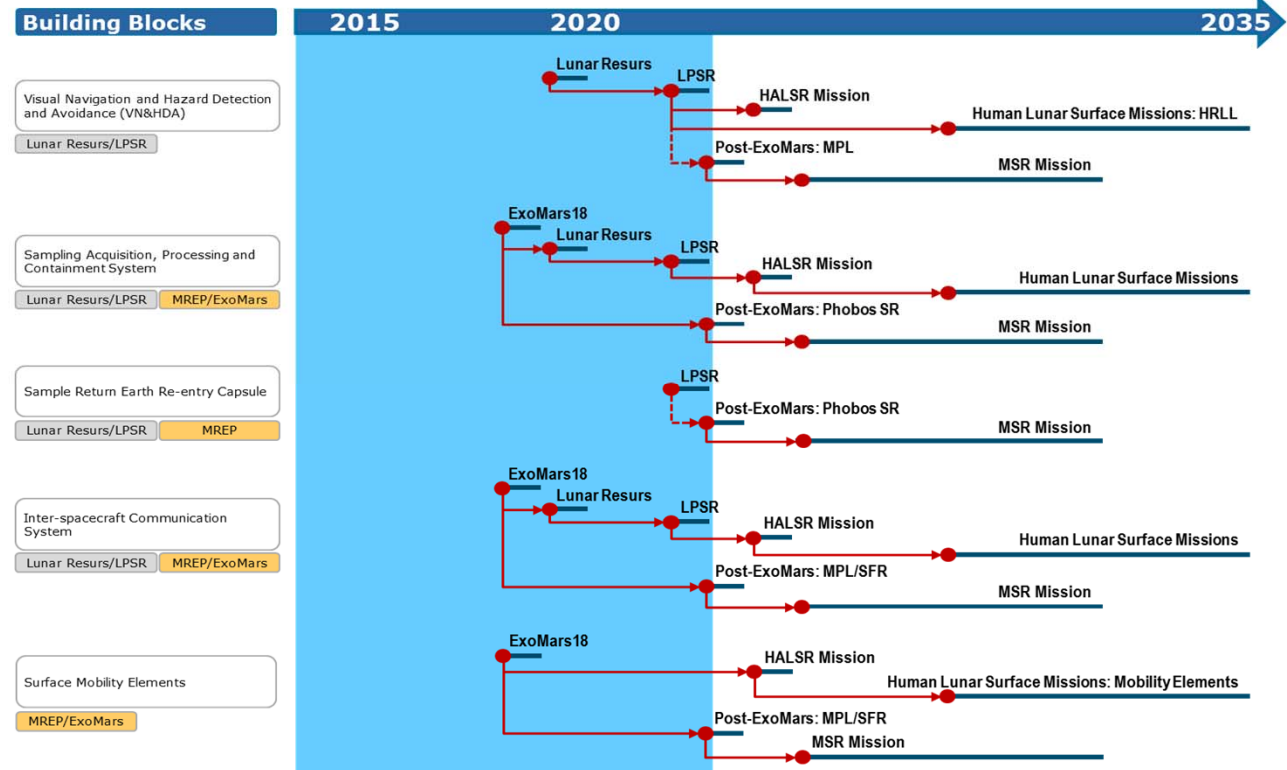


Figure above shows (a detail of) the preparation of this building blocks by the planned missions up to the 2020 timeframe as well as opportunities for evolving these building blocks towards securing applications in international post 2020 exploration mission scenarios - see Status of ESA's Space Exploration Strategy" ESA/CWG(2014)

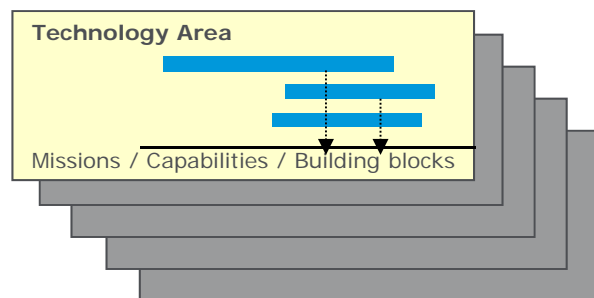
TYPES OF ROADMAPS



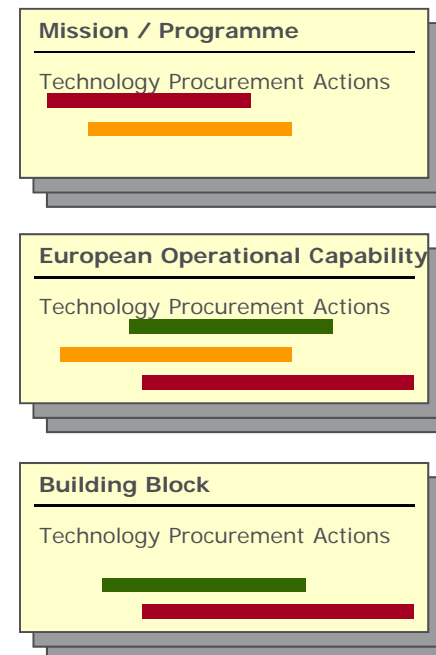
The database tools allows to generate different types of roadmaps, tailored to different use (Delegations, Mission/Programme management, Technology procurement, etc.):

"Standard" Roadmaps

➤ **Technology** based Roadmaps



"Reverse" Roadmaps

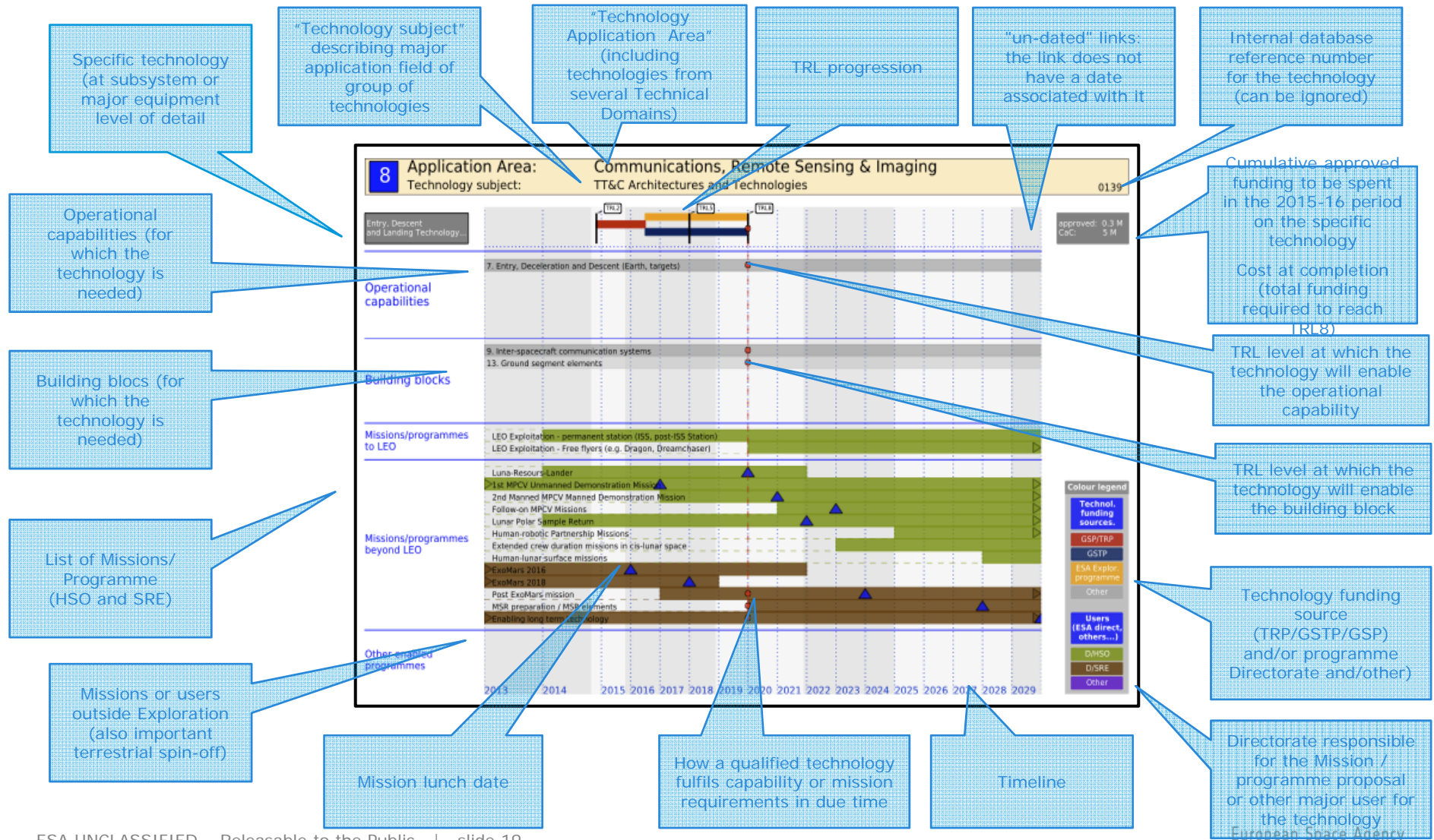


➤ **Mission** based Roadmaps

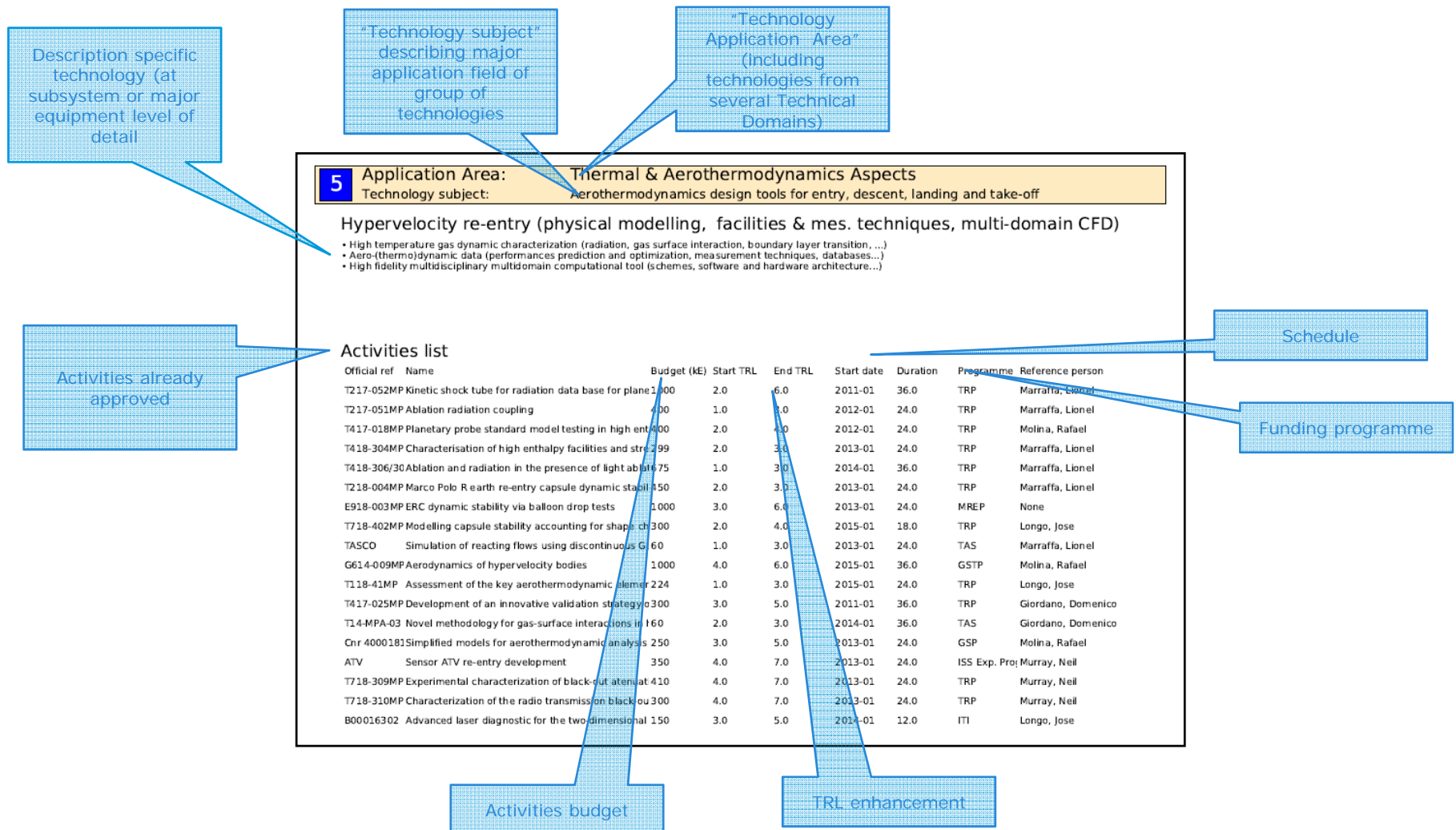
➤ **Operational Capability** based Roadmaps

➤ **Building Blocks** based Roadmaps

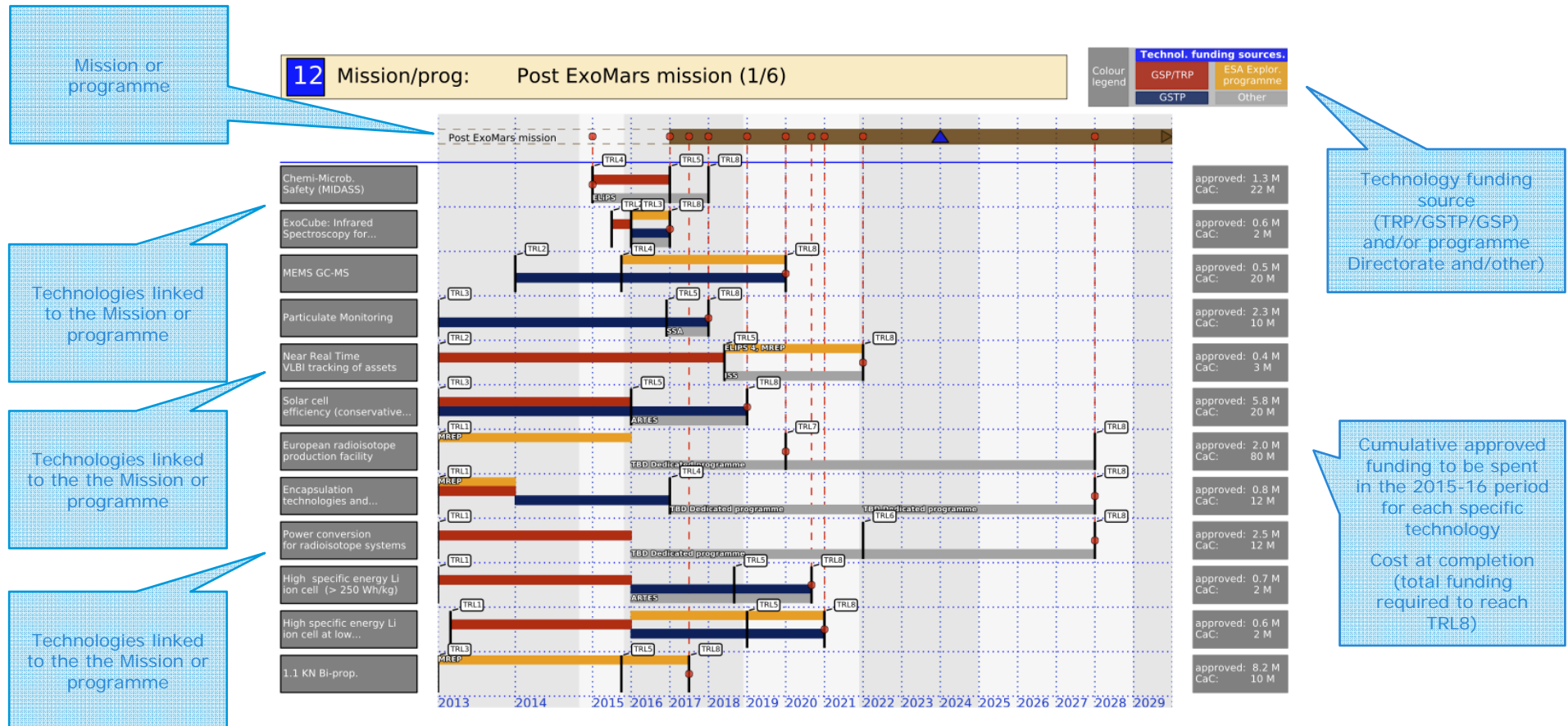
HOW TO READ A CHART IN TECHNOLOGY BASED ROADMAPS (1/2)



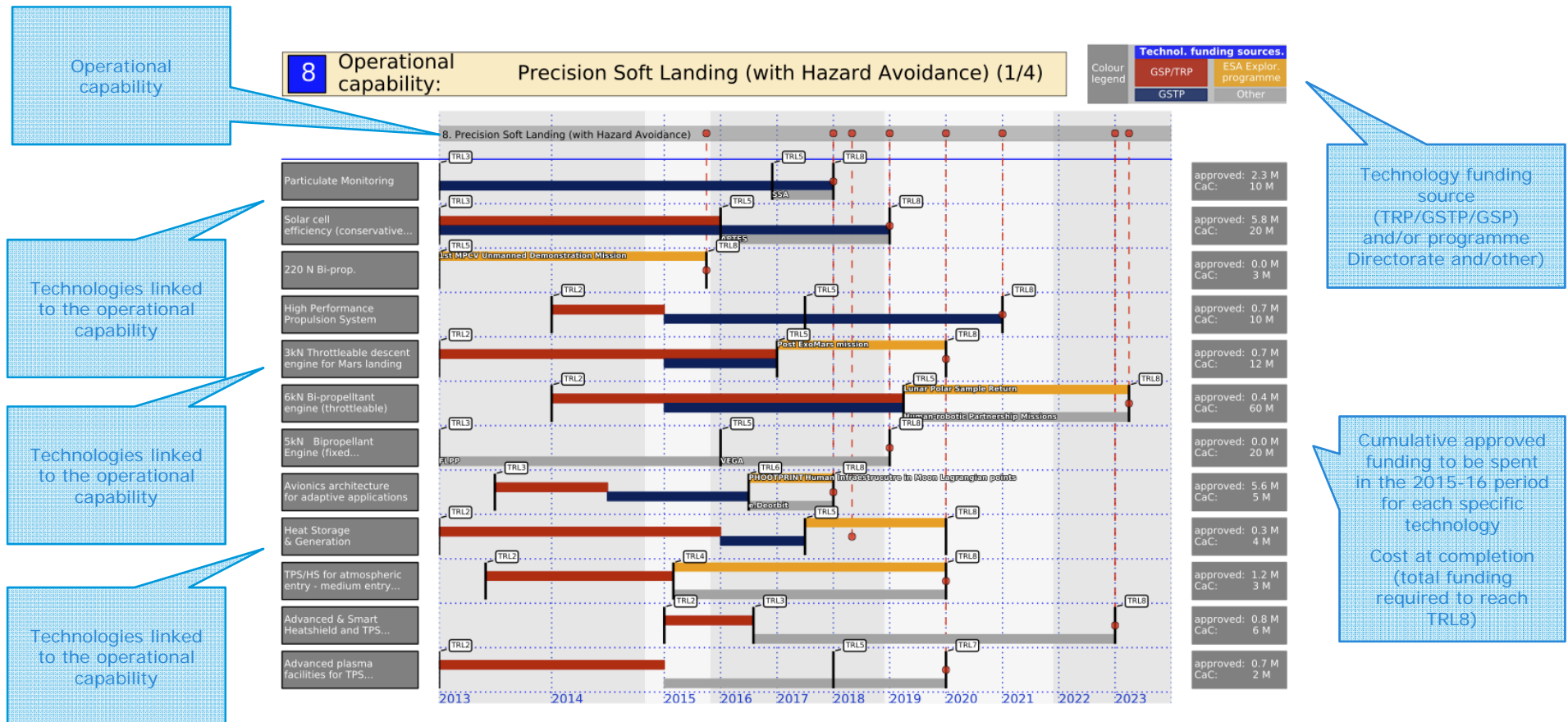
HOW TO READ A CHART IN TECHNOLOGY BASED ROADMAPS (2/2)



HOW TO READ A CHART IN MISSIONS BASED ROADMAPS



HOW TO READ A CHART IN OPERATIONAL CAPABILITIES BASED ROADMAPS



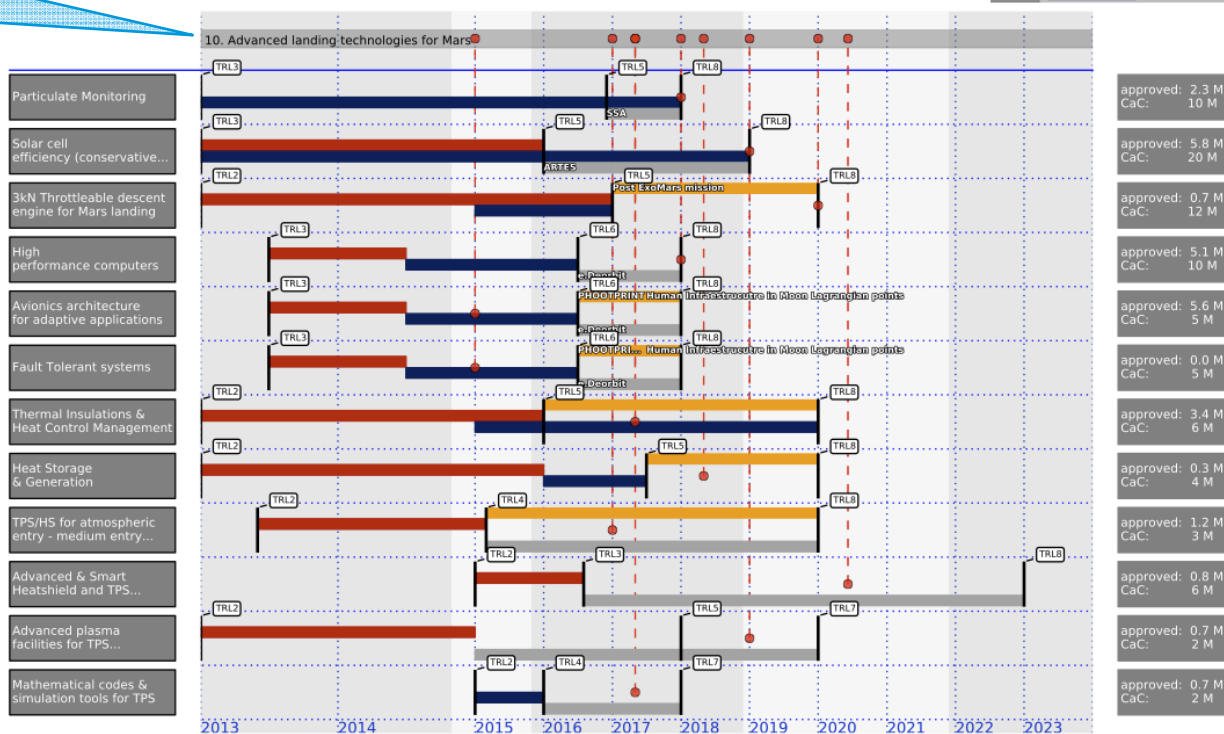
HOW TO READ A CHART IN BUILDING BLOCKS BASED ROADMAPS



Building Block

10 Building block: Advanced landing technologies for Mars (1/3)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other



Technologies linked to the Building Block

Technologies linked to the Building Block

Technologies linked to the Building Block

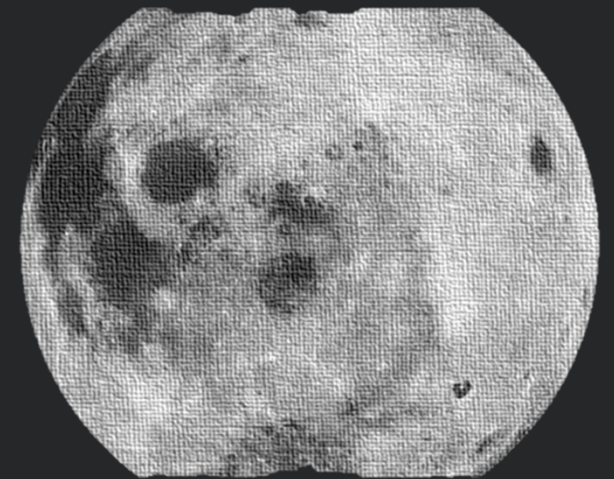
Technology funding source (TRP/GSTP/GSP) and/or programme Directorate and/or other

Cumulative approved funding to be spent in the 2015-16 period for each specific technology

Cost at completion (total funding required to reach TRL8)



BUILDING BLOCKS FOR MOON MISSIONS



THE BUILDING BLOCKS FOR MOON MISSIONS



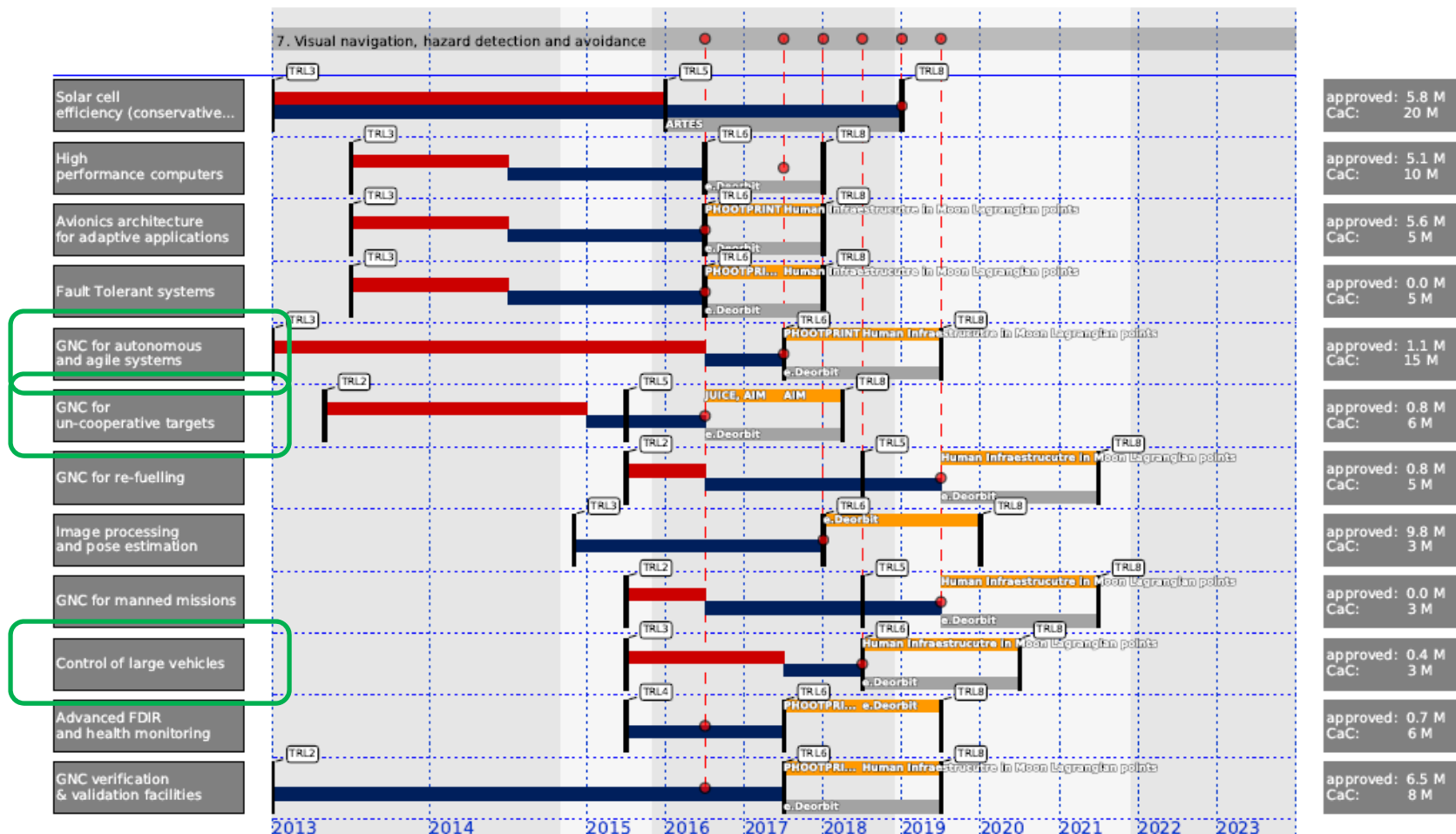
- Visual navigation, hazard detection and avoidance;
- Sample acquisition, processing and containment system;
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- Inter-spacecraft communication systems;
- Surface mobility elements;
- Advanced Mars landing systems;
- Miniaturized avionics;
- Planetary protection;
- Tele-robotic and autonomous control systems;
- Rendezvous with non-cooperative targets and docking systems;
- Storable propulsion modules and equipment;
- Habitation systems;
- Ground segment elements.

VISUAL NAVIGATION, HAZARD DETECTION AND AVOIDANCE



7 Building block: Visual navigation, hazard detection and avoidance (1/3)

Colour legend	Technol. funding sources.	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

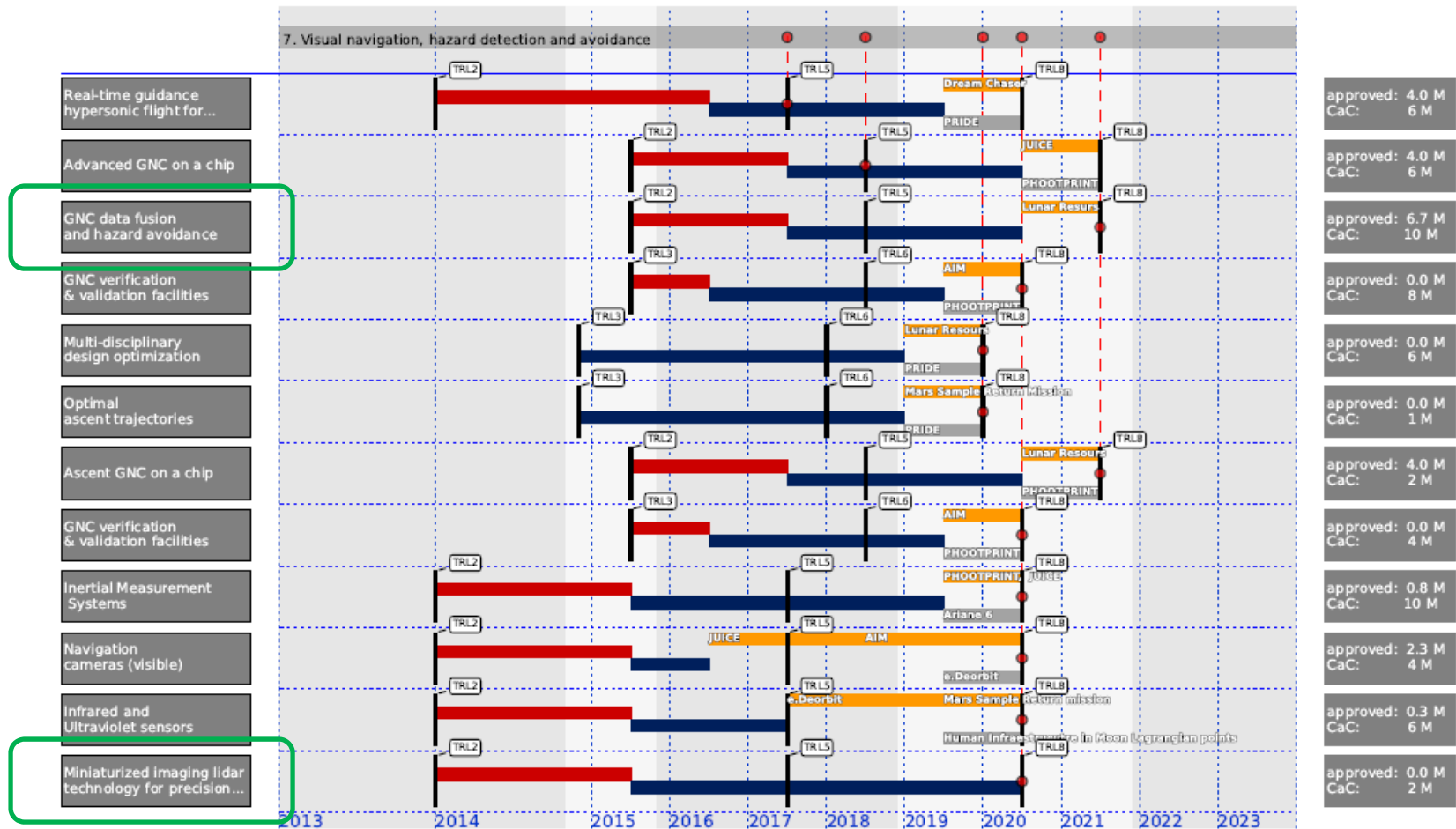


VISUAL NAVIGATION, HAZARD DETECTION AND AVOIDANCE



7 Building block: Visual navigation, hazard detection and avoidance (2/3)

Colour legend	Technol. funding sources.	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

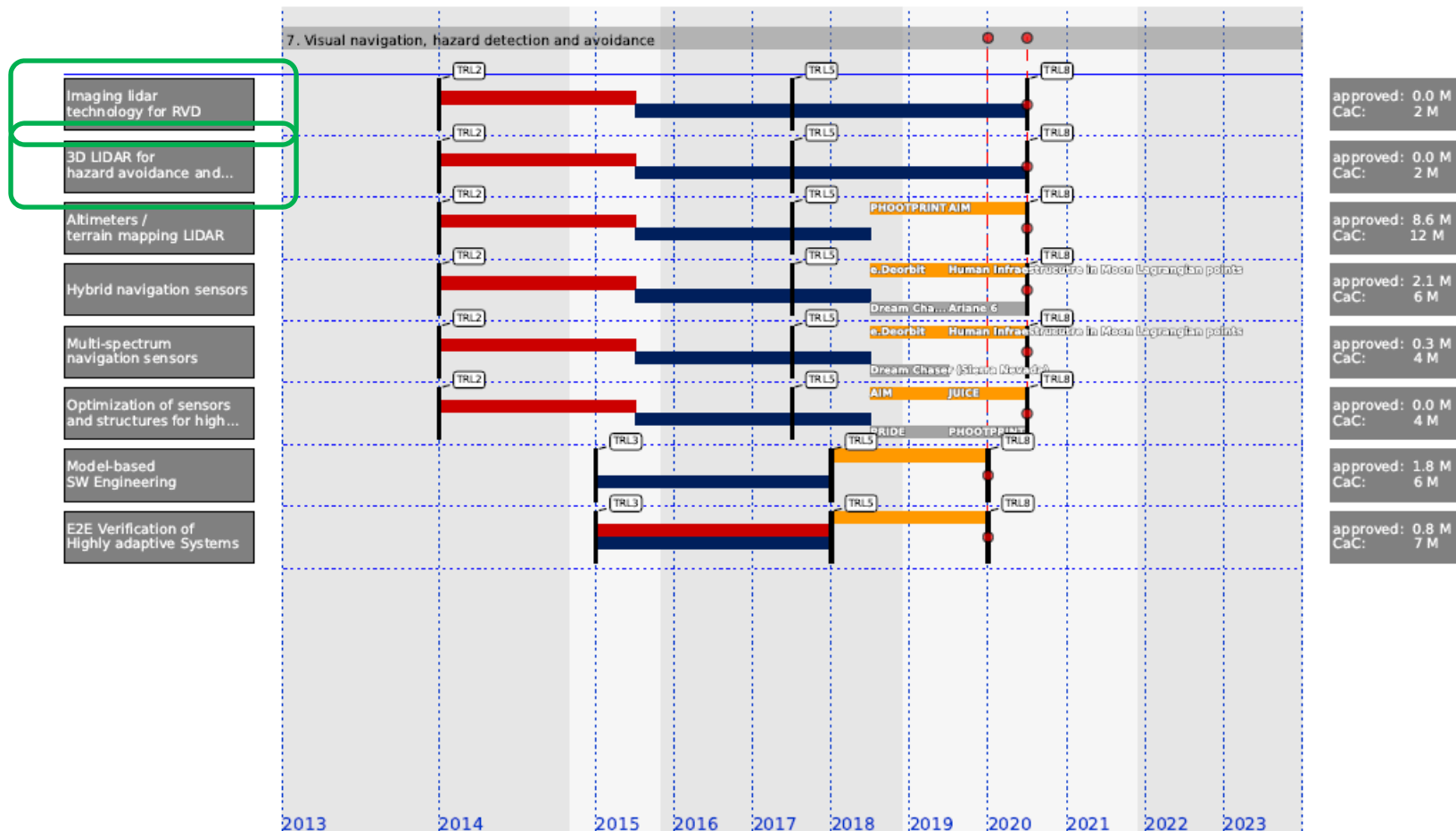


VISUAL NAVIGATION, HAZARD DETECTION AND AVOIDANCE



7 Building block: Visual navigation, hazard detection and avoidance (3/3)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

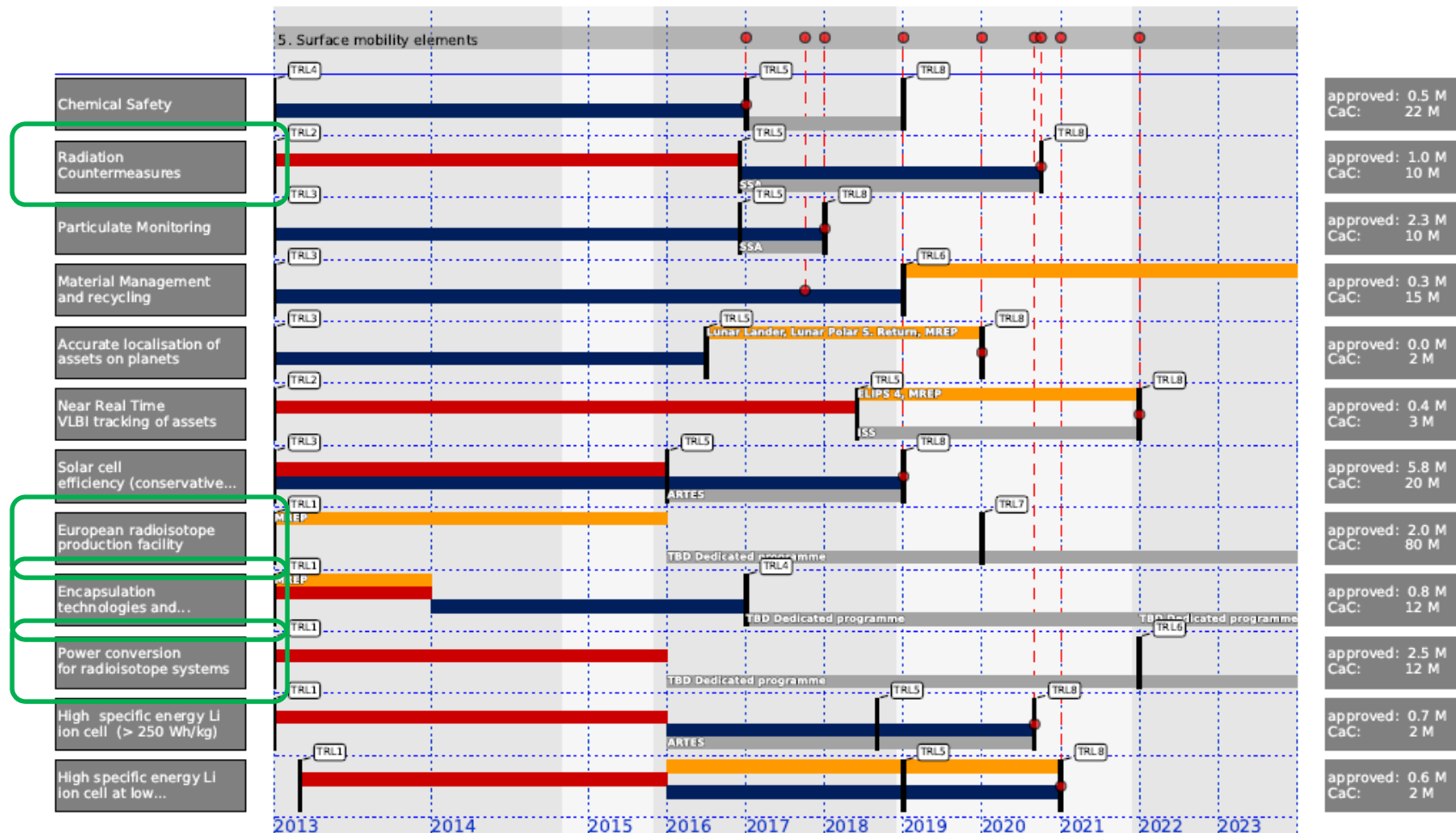


SURFACE MOBILITY ELEMENTS



5 Building block: Surface mobility elements (1/2)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

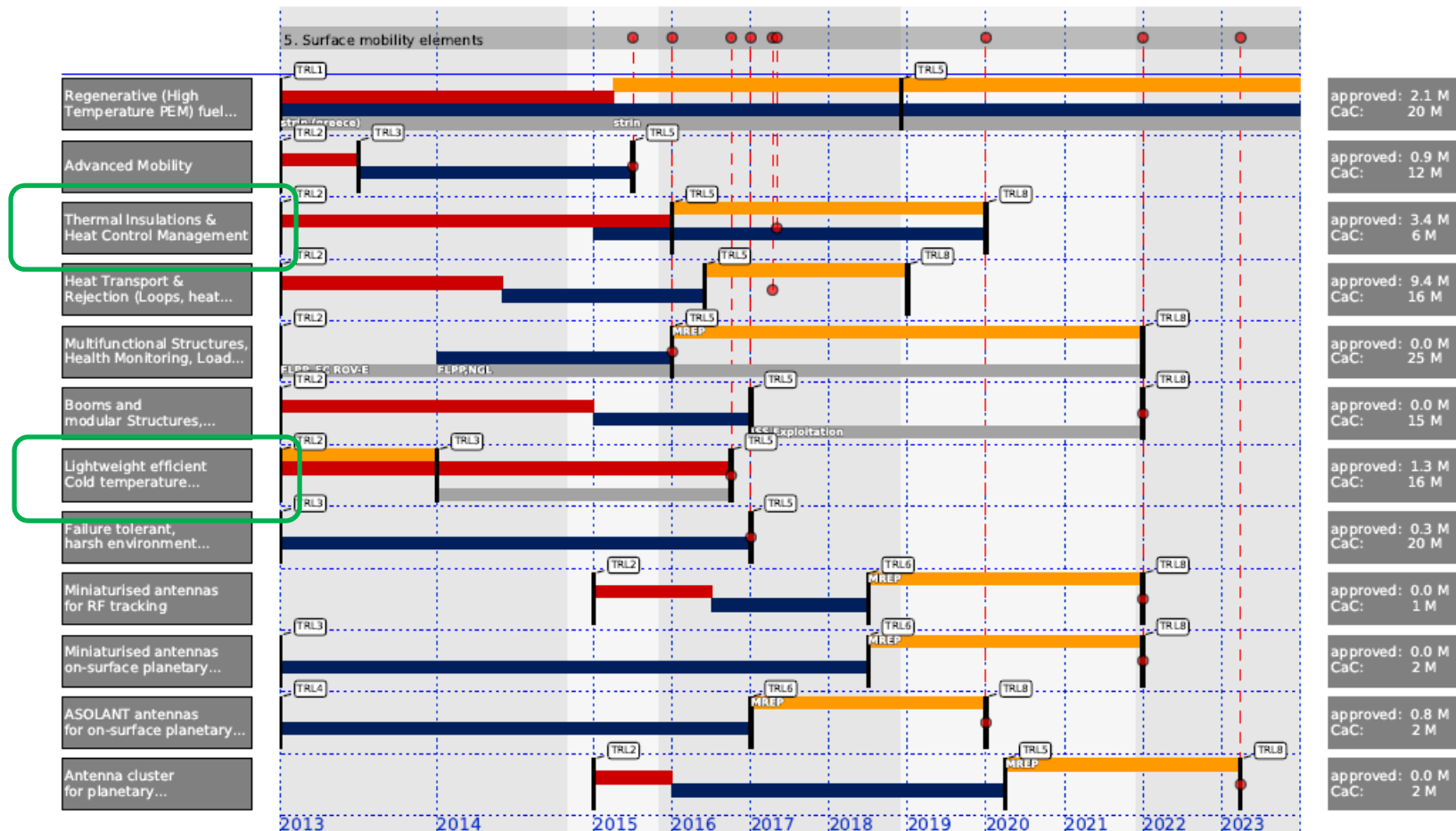


SURFACE MOBILITY ELEMENTS



5 Building block: Surface mobility elements (2/2)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

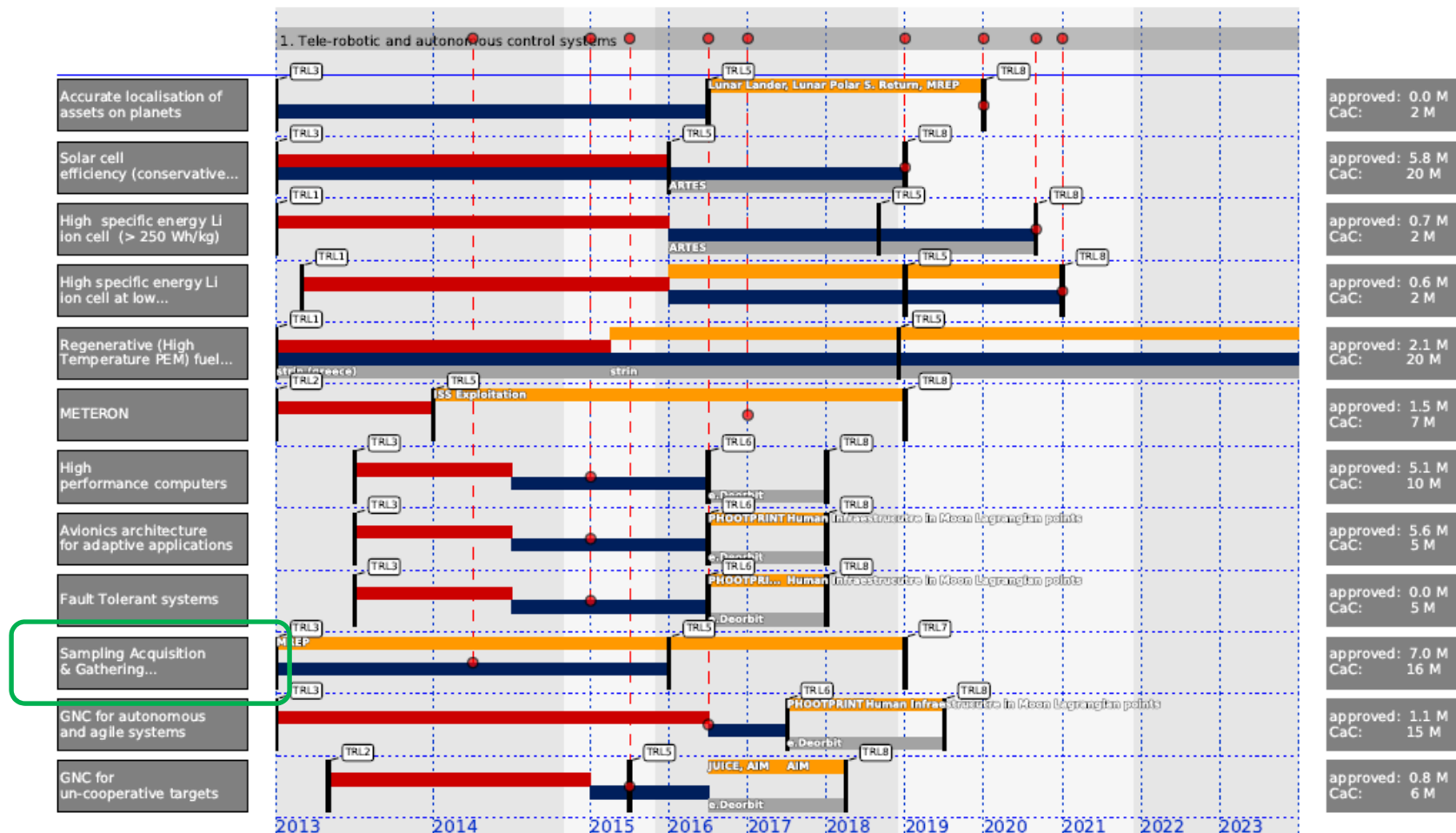


TELEROBOTICS AND AUTONOMOUS CONTROL SYSTEMS



1 Building block: Tele-robotic and autonomous control systems (1/2)

Colour legend	Technol. funding sources.	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

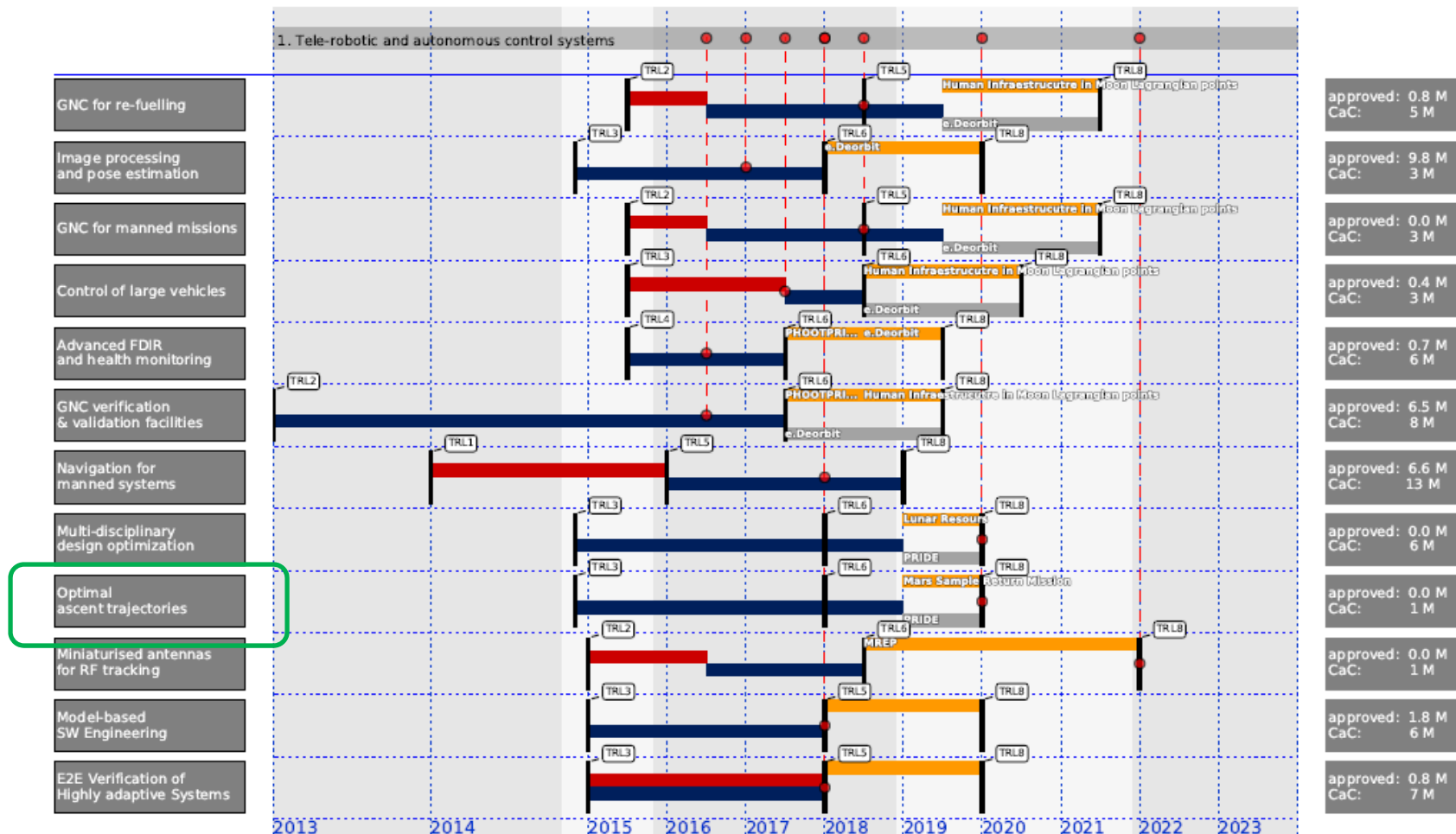


TELEROBOTICS AND AUTONOMOUS CONTROL SYSTEMS



1 Building block: Tele-robotic and autonomous control systems (2/2)

Colour legend	Technol. funding sources.	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

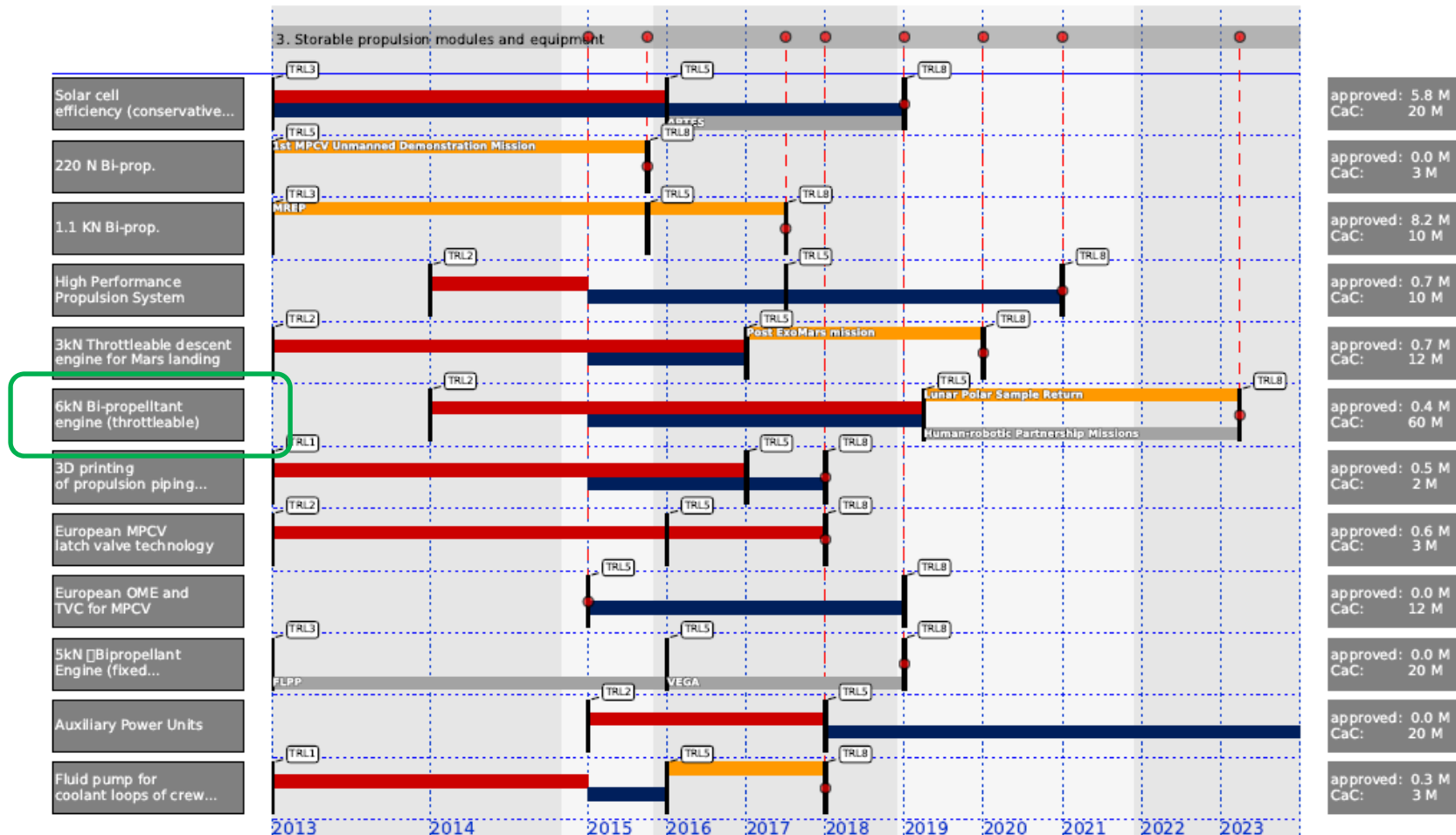


STORABLE PROPULSION MODULE AND EQUIPMENT



3 Building block: Storable propulsion modules and equipment (1/2)

Colour legend	Technol. funding sources.	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

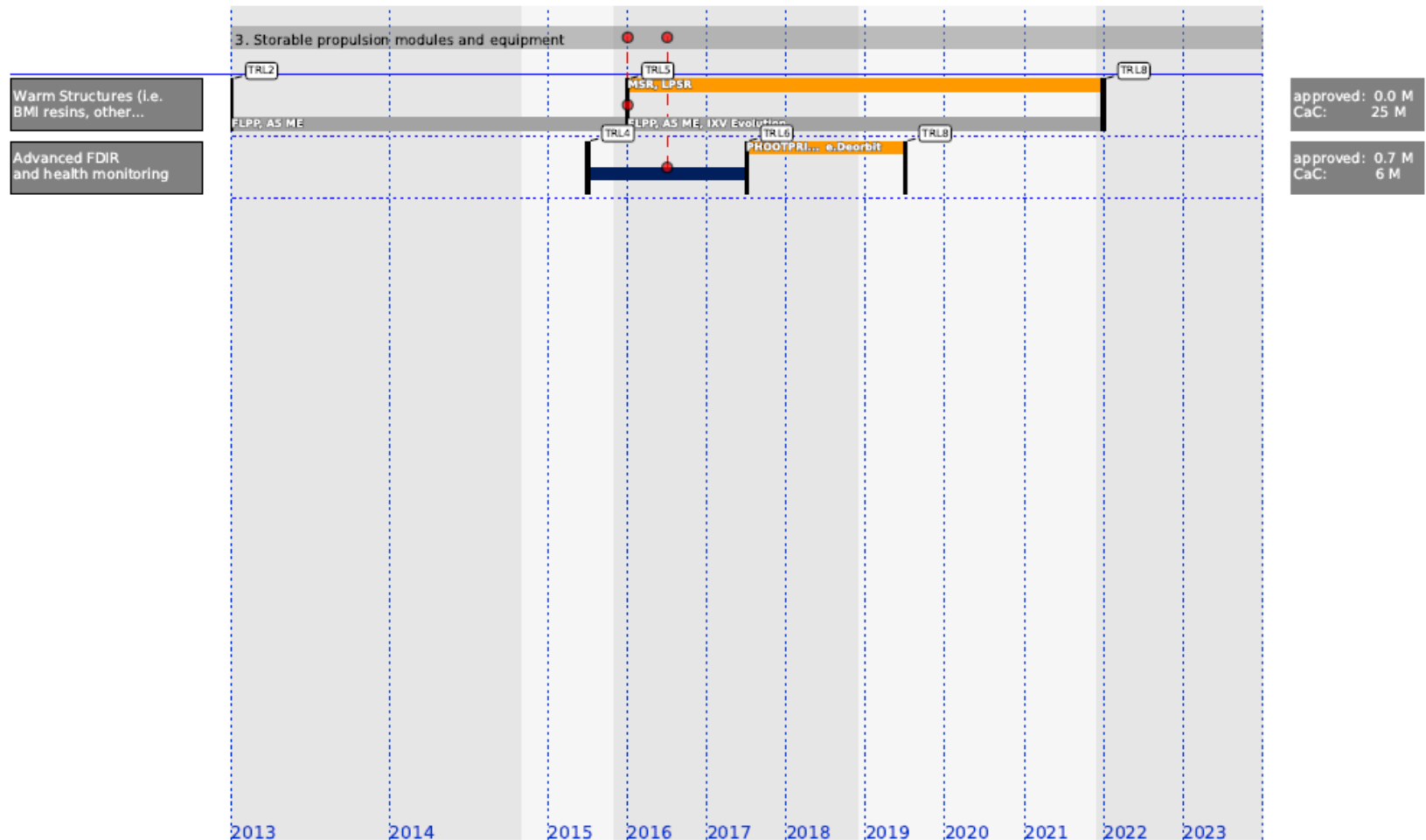


STORABLE PROPULSION MODULE AND EQUIPMENT



3 Building block: Storable propulsion modules and equipment (2/2)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

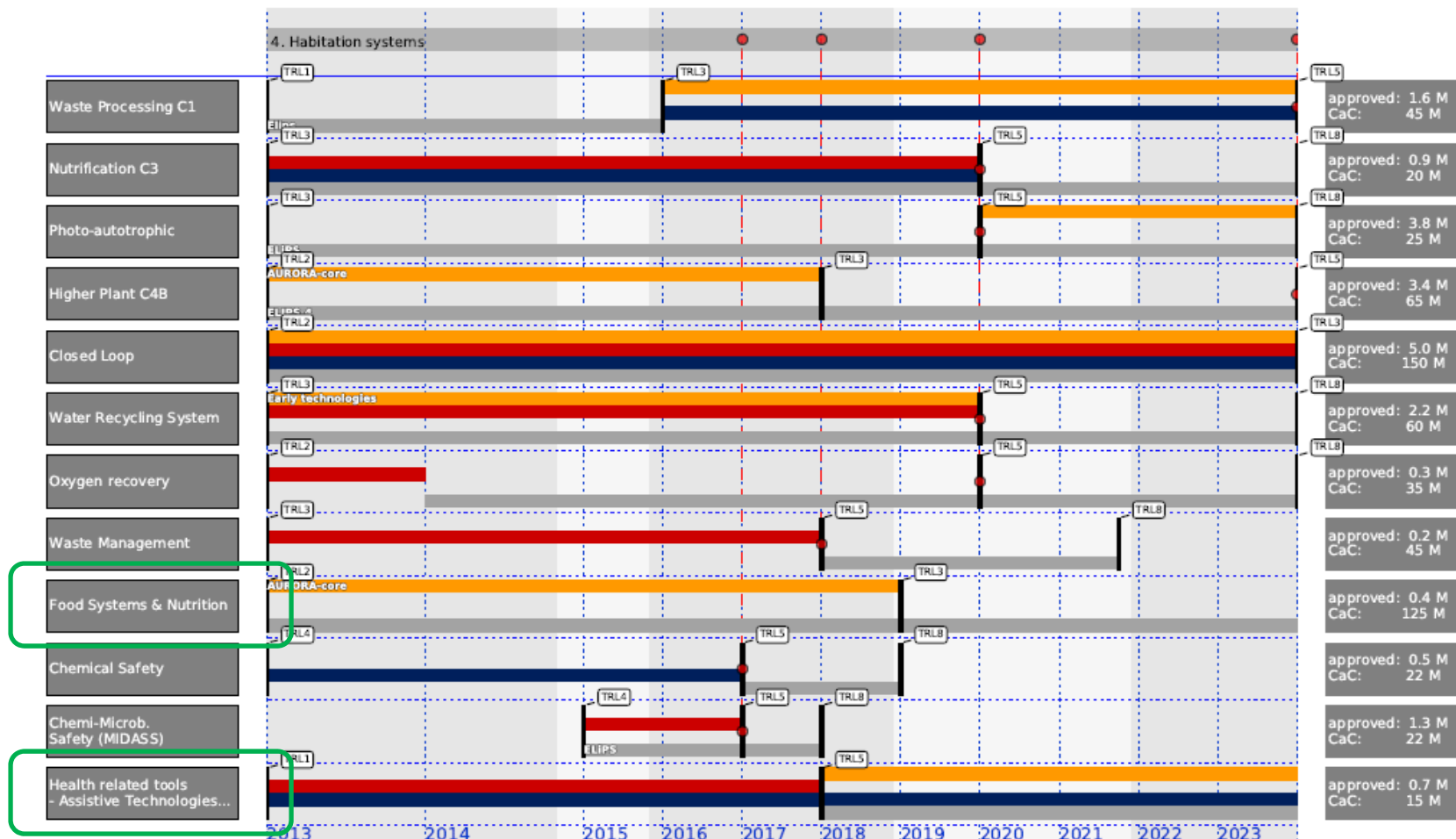


HABITATION SYSTEMS



4 Building block: Habitation systems (1/4)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

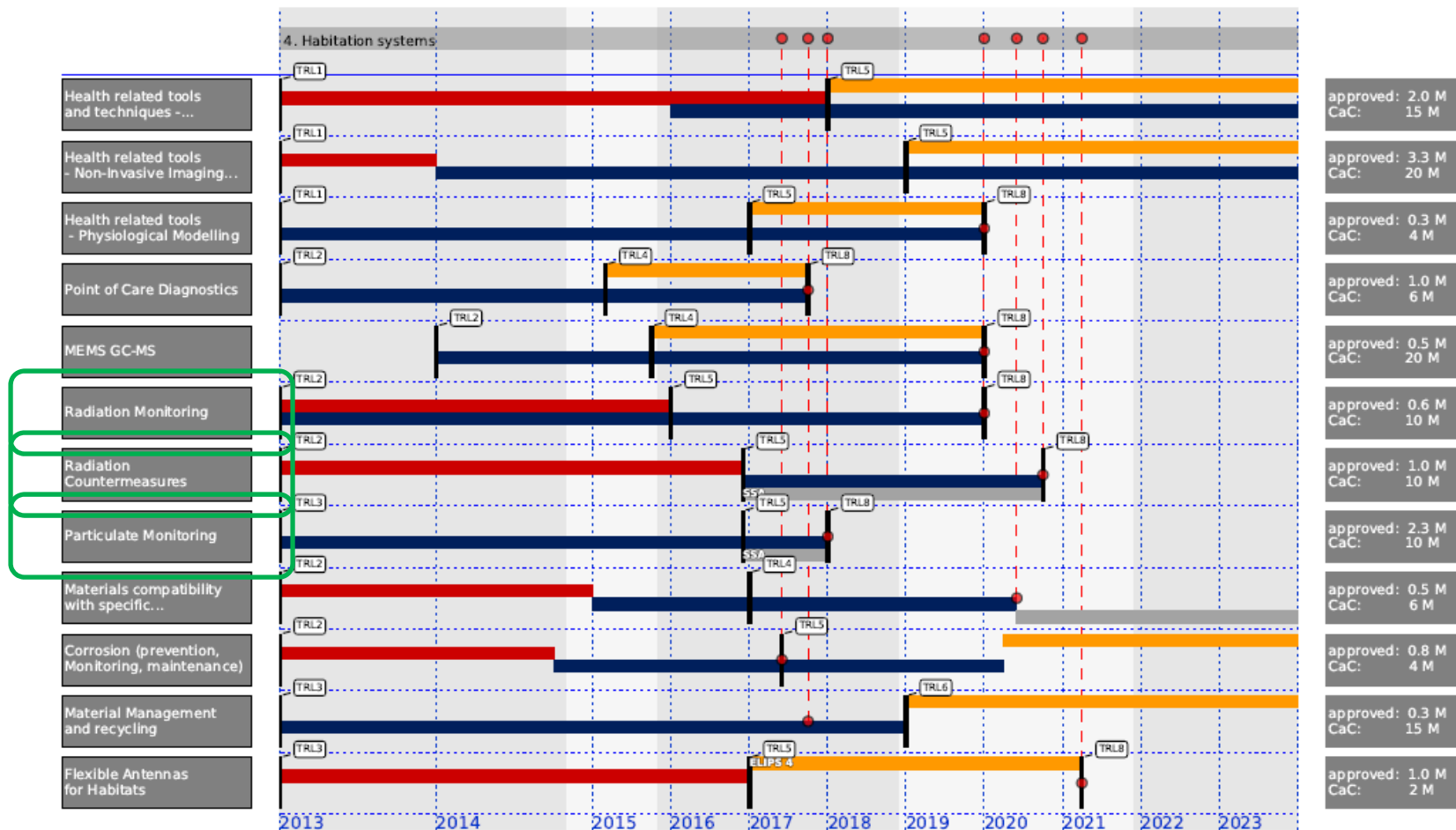


HABITATION SYSTEMS



4 Building block: Habitation systems (2/4)

Colour legend	Technol. funding sources.	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

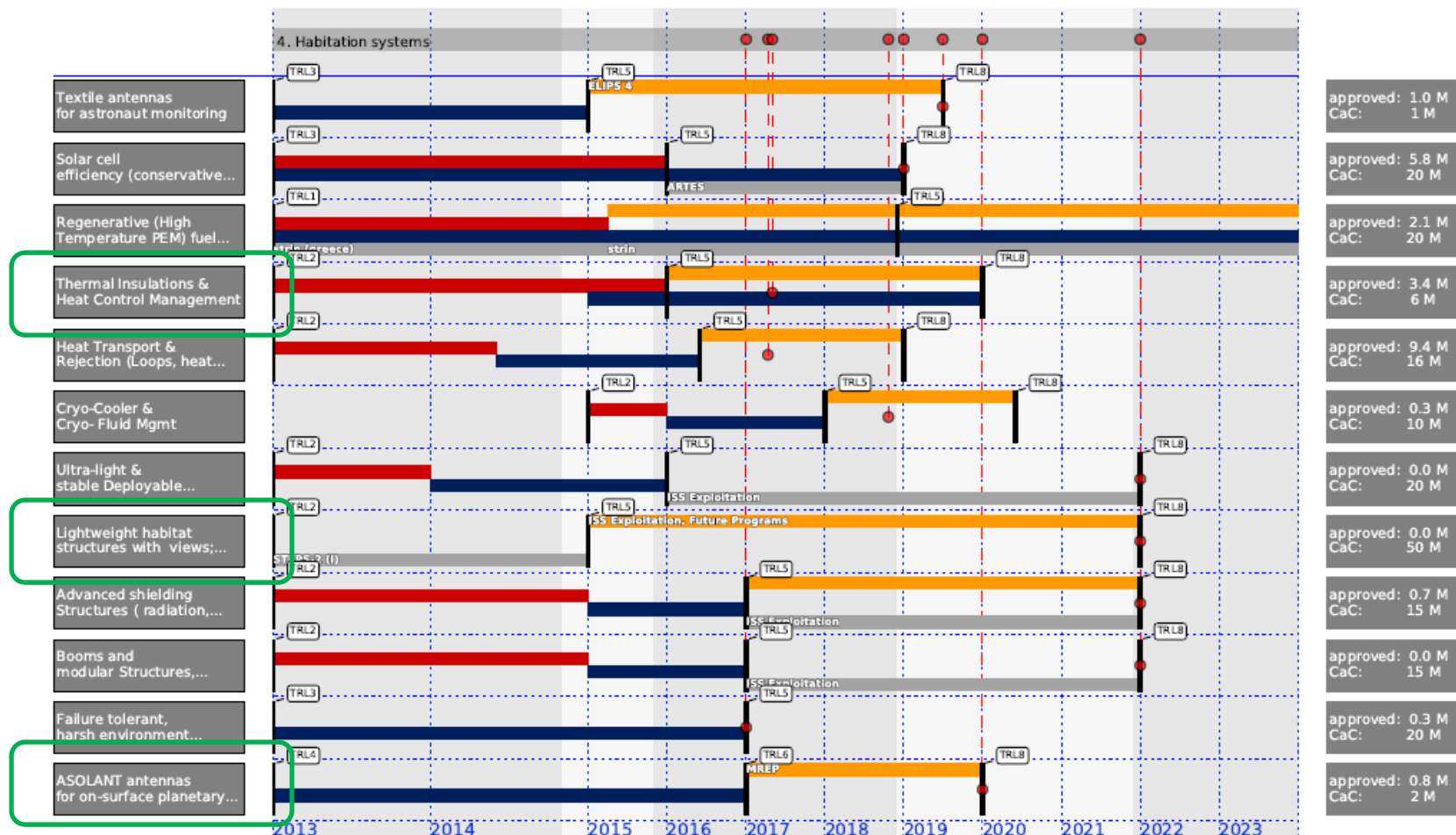


HABITATION SYSTEMS



4 Building block: Habitation systems (3/4)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

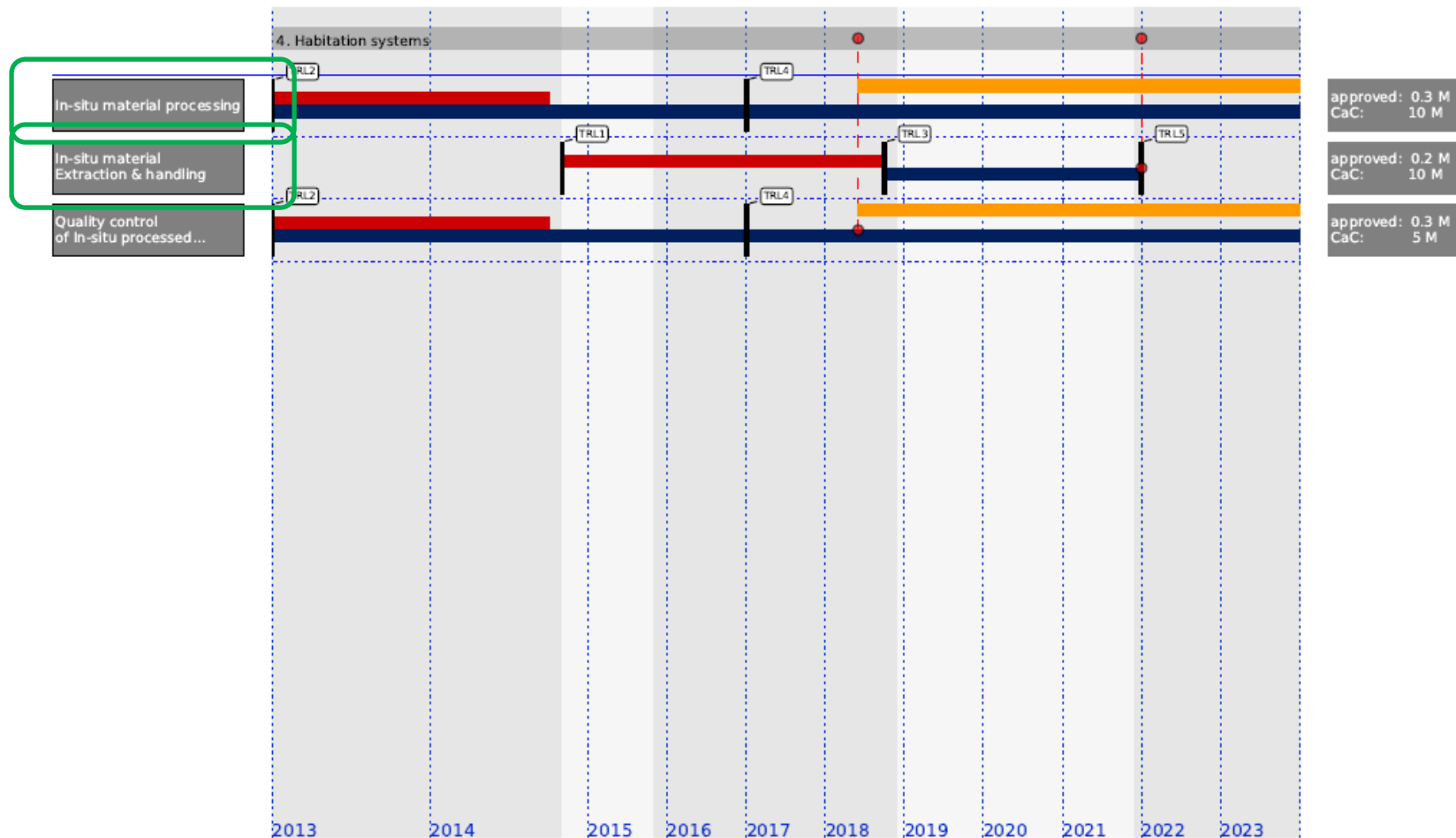


HABITATION SYSTEMS

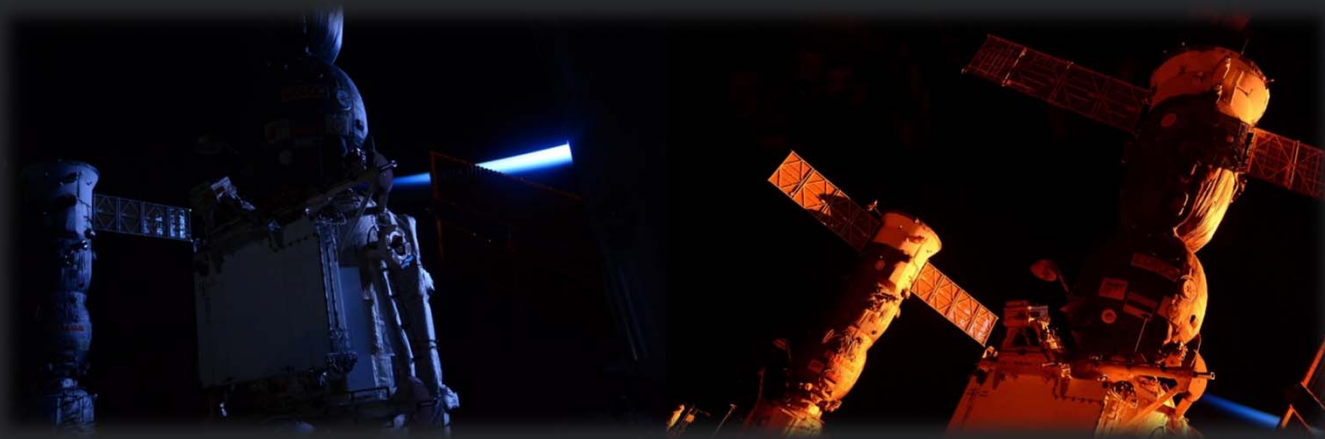


4 Building block: Habitation systems (4/4)

Colour legend	Technol. funding sources	
	GSP/TRP	ESA Explor. programme
	GSTP	Other

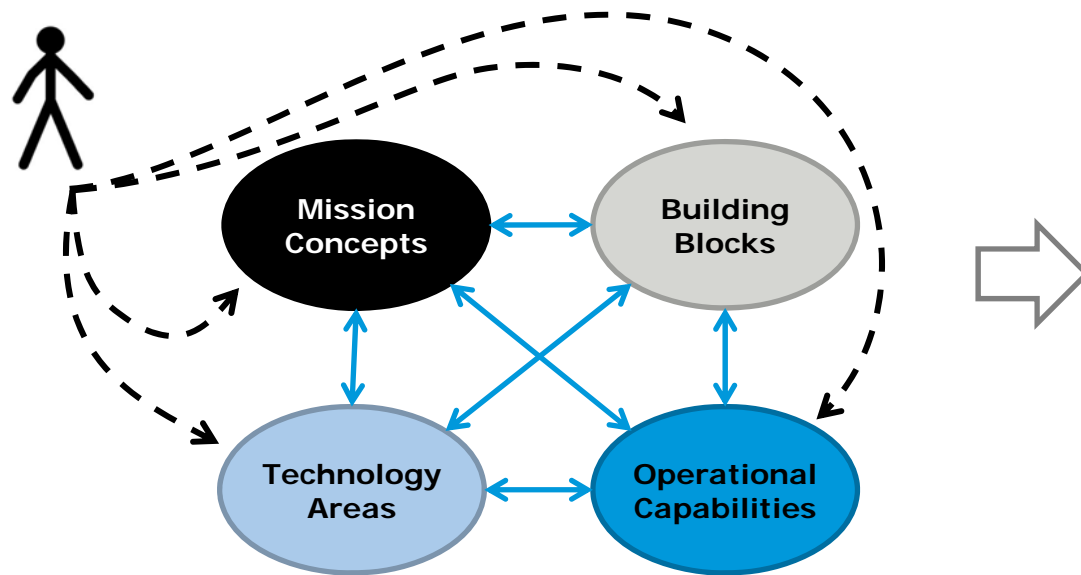


IMPROVING THE TECHNOLOGY ROADMAPS FOR EXPLORATION



CRITICAL ASSESSMENT AND IMPROVED USE OF TECHNOLOGY ROADMAPS

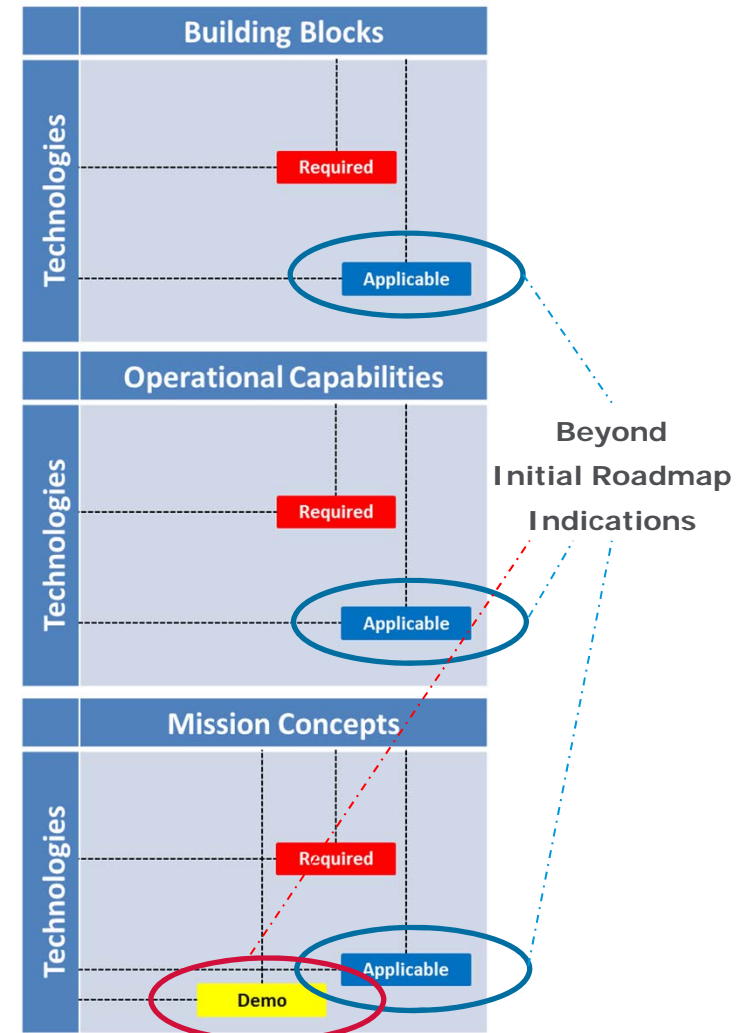
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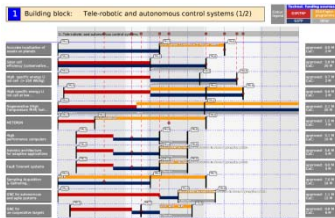
Main purposes:

- **Prioritisation** of Technologies and Mission Concepts (including test and demos);
- New **Path to TRL increase** proposed for all the technologies involved.

Applicability analysis

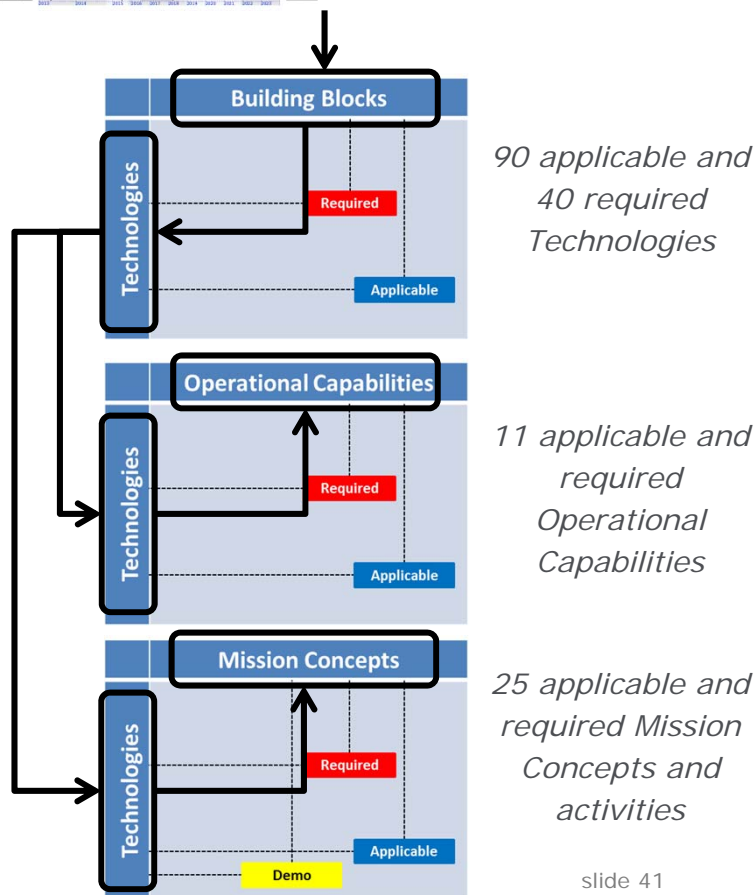


EXAMPLE



INPUTS (Building Blocks):

1. Tele-robotic and autonomous control systems;
2. Storable propulsion modules and equipment.



slide 41

Technologies and Mission Concepts prioritisation

TRL increase path proposed for all the technologies involved

OUTPUTS:

Only 8 Mission Concepts (including tests and demos) are selected for TRL increase purposes:

1. Theoretical principles formulation (TRL 2), 3 techs;
2. Analytical proof (TRL 3), 37 technologies;
3. Lab. components/breadboard validation (4), 100 tech;
4. Components/breadboard valid. in not controlled environ. (TRL 5), 114 tech;
5. Sys./subs. prototype demo. in not controlled environ. (TRL 6), 129 tech;
6. Complete system flight qualification (7) and Orbital element launch or Luna-Resours-Lander (8 and 9), 130 technologies.

		ExoCube: Infrared Spectroscopy for Ast	MEMS GC-MS
Earth	Theoretical principles formulation		
	Analytical proof	3	
	Experimental proof		
	Laboratory components/breadboard validation	4	
	Components/breadboard valid. in not controlled env	5	5
	Sys./subs. prototype demo. in not controlled environ	6	6
LEO	Components/breadboard validation		
	System/subsystem prototype demonstration		
	Complete system flight qualification	7	7
	LEO Exploitation - permanent station (ISS, post-ISS S		
	1st MPCV Unmanned Demonstration Mission		
	2nd Manned MPCV Manned Demonstration Mission		
	LEO Exploitation - Free flyers (e.g. Dragon, Dreamcha		
	Follow-on MPCV Missions		
Moon	Orbital element launch	9	9
	Luna-Resours-Lander	8	8
	Lunar Polar Sample Return		
	Extended crew duration missions in cis-lunar space		
	Human-lunar surface missions		
	Human-robotic Partnership Missions		
	Human Assisted Sample Return		



THANK YOU

European Space Agency