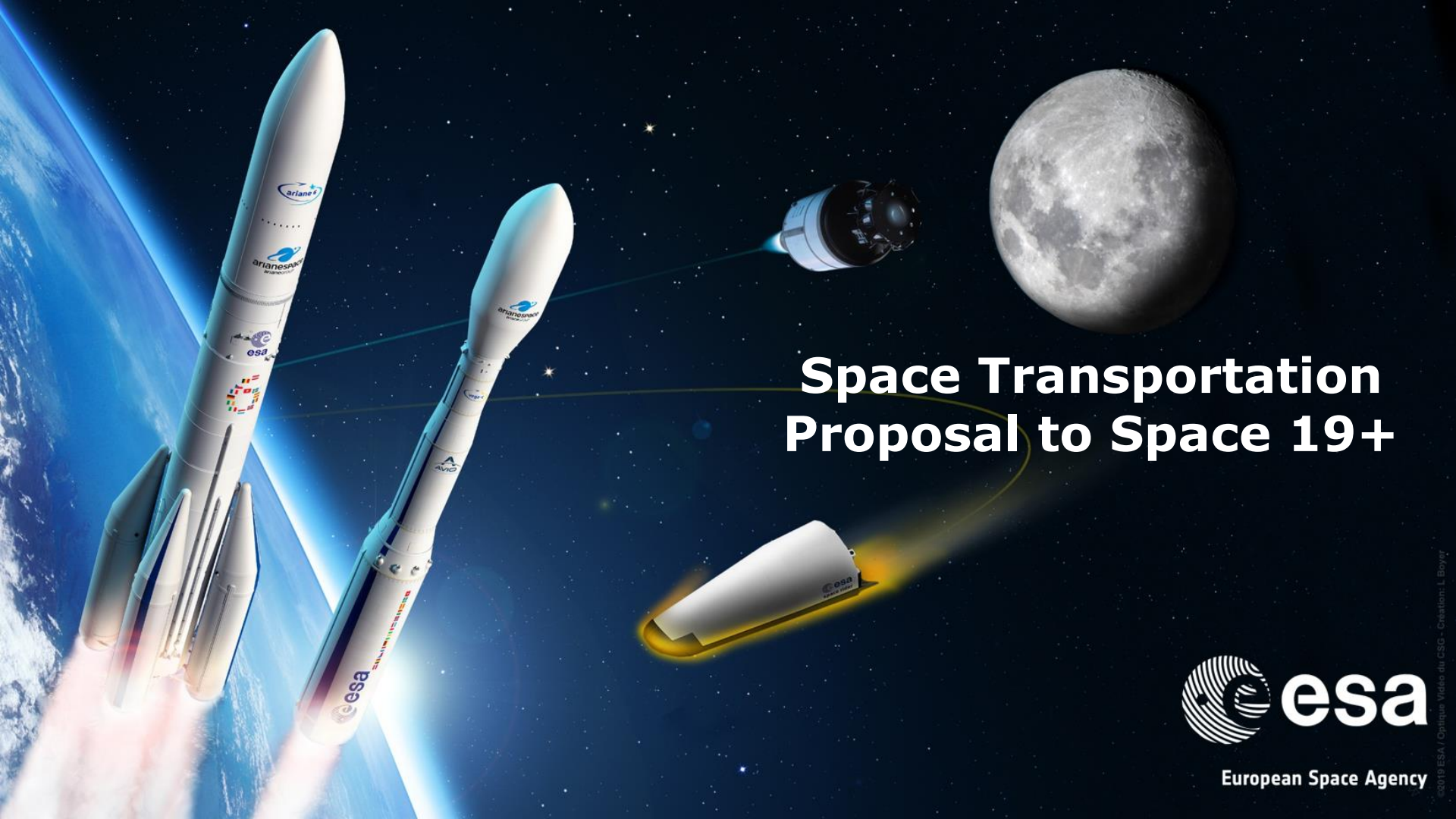

Space Transportation
Proposal to Space 19+
esa
European Space Agency
©2019 ESA / Optique Vidéo du CSG - Creation: L. Boyer

STS Main Elements at Space 19+

Space19

- *Inspiration*
- *Competitiveness*
- *Responsibility*


esa
Future Space Transportation preparation at Space 19+: FLPP
- 30th September 2019, Bruxelles -
#Space19plus
Space19

Future Space Transportation: European context

- A6/Vega-C developments on track with a lot of work ahead,
- New challenges are incoming with maturity in 2025
- Horizon in 2022 where:
  - Ariane and Vega exploitation will be on-going
  - GEO/MEO/LEO markets stabilised, or at least more visibility
  - Newspace will have passed reality check

☞ **2019-23** period devoted to **preparation** of innovative operational capabilities **for 2025 and beyond**

☞ **2022** will be time to **decide** – or not – **new development** phase

The next decade: some drivers

Drivers 2025+ horizon

Space Economy

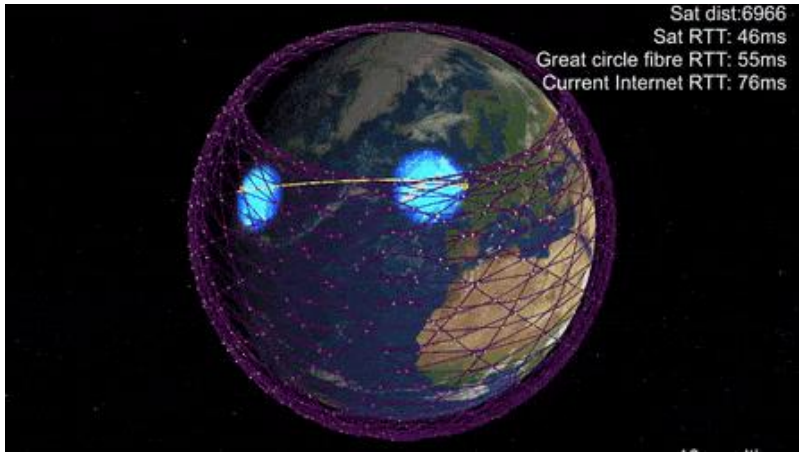
•5G, IoT, private infrastructure, …

Spacecraft Technology

•1G Mega Const, HAPS, Servicing, …

Launch Competition

•Ariane 6/VEGA-C, BFR, New Glenn, Micro, ...



Commercial space and space transportation become part of the « **Data world** »
ie: deliver the right data to the right place at the right moment

Institutional space will remain a major player, especially in **exploration**

Future Space Transportation: 2019-2023 period

For resilience in view of 2022 milestone, help prepare our sector to deliver end to end Space Transportation services.

At Space19+ three objectives:

1. Mid/Long-term **competitiveness** improvement of launch services for institutional missions:

   Prometheus, ETID, Avionics, Themis/Reusability, Advanced Technologies…

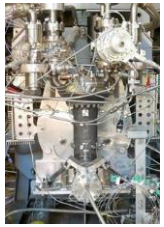
2. Increase of the **versatility** of Space Transportation:

   Space Logistics, Kick Stage, Green Propulsion/Berta, Advanced Technologies, In Space PoC mission…

3. **Diversification** of the Space Transportation processes:

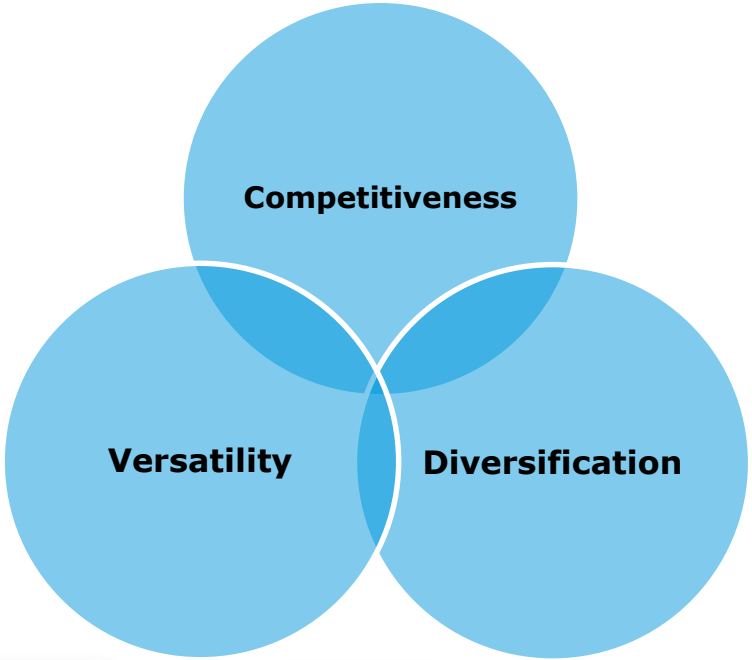
   Advanced Technologies, Startup and NewTech, Accelerators, Spacecraft manufacturers…

Preparing Future Space Transportation

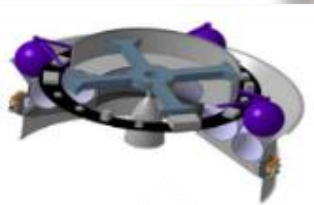



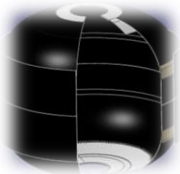




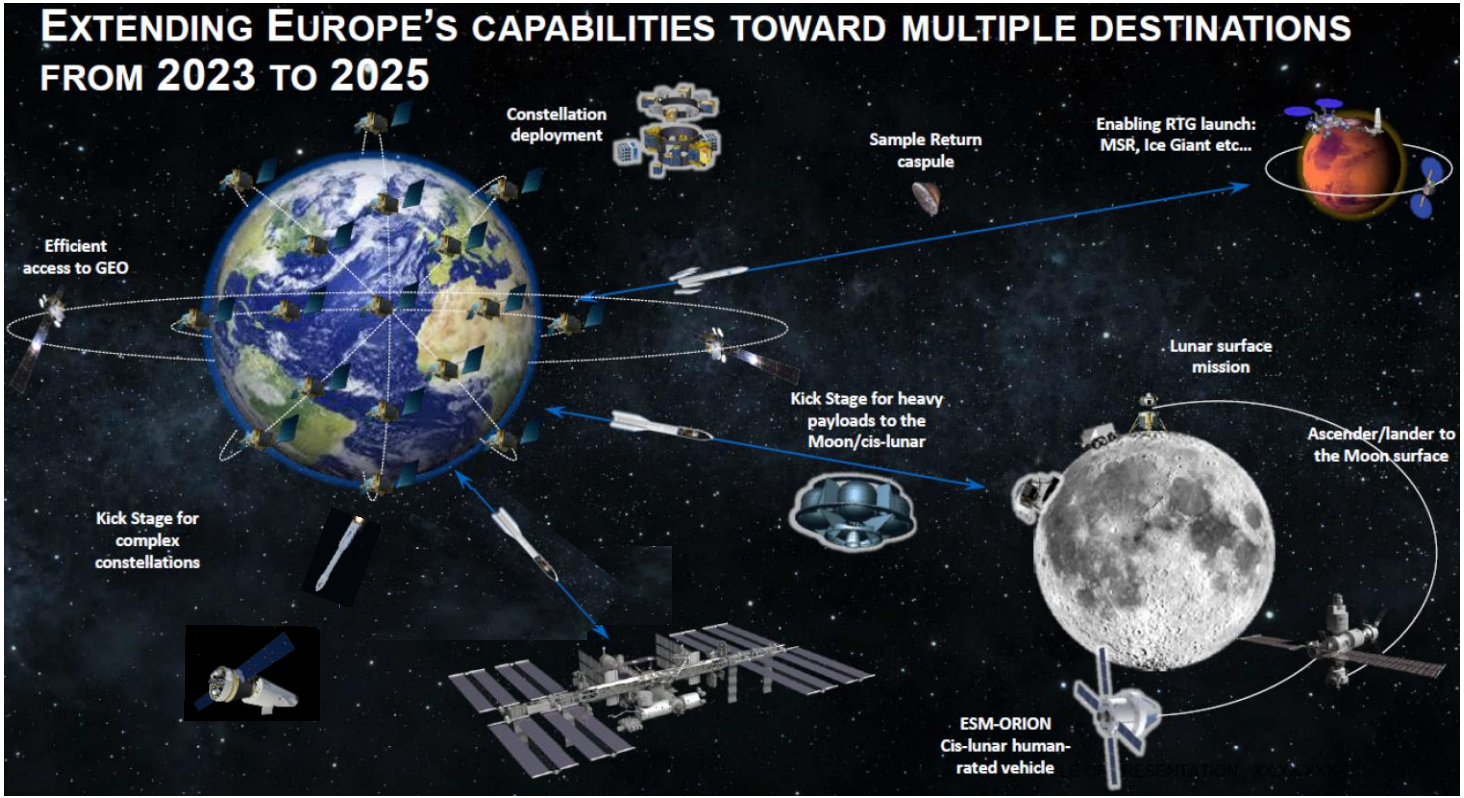





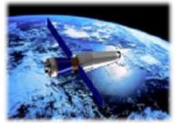
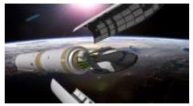
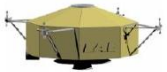




Preparing Future Space Transportation



...towards Space Logistics

Enabling bricks

Ariane 6 & Vega-C and evolutions	Modular & flexible dispensers and kickstages	In-orbit Commercial Services	Strategic cooperation on recurring cis-lunar station access	Towards significant European role on the lunar surface
 Ariane 6 2020  Vega-C 2019	 Dispenser flexibility	    Servicing vehicles launched by Arianespace	  Cooperation on Orion European Service Module & Competitive cargo	 Courtesy of PTS2018  Sovereign European payload delivery & Towards human rated access in international cooperation
  Preparation of evolution bricks	  Rideshare & Kick-stage family			

Demonstrators

- Precursors of future products
- a large experience in FLPP
- a high success rate

A web of demonstrators

LOW COST & VERSATILITY

Low Cost Light Weight UPPER STAGE technologies

PHOEBUS
ComET
SCOUT
CCTTEC
MT4BUS
LTIP
FLINT

2

§ 6.1.2.

EXPAN (ETID)
§ 6.1.2.4.

3

PROMETHEUS
§ 6.

REUSABILITY

THEMIS
§ 6.3.

1

REEN KICK STAGE
§ 6.1.2.1.

GREEN STORABLE ENGINE

THROTTLING

THROTTLING
§ 6.1.2.2.

DTV

DTV +
§ 6.1.2.3.

DROP TEST

HYBRID PROPULSION

EXPLORATION

MICROLAUNCHERS

1- Green Kick Stage

FLPP Programme Proposal § 6.1.2.1 & 6.1.2.2.

Moon transfer & orbiting
4 to 5 days missions

High perfo direct MEO & GEO

Multi SSO/LEO

Contribution to Space Logistics

A complete project, gathering all fields of Space Transportation technologies

5 kN KICK STAGE
FULL SCALE DEMO 2020-23

Ultra light tanks
CFRP structure
NG avionics
Innovative AOCS

Green BERTA engine
2018-22
Full ALM combustion chamber
Green propellants
E-pumps
Throttling

2- Low-Cost /Light Weight Upper Stage for Ariane

FLPP Programme Proposal § 6.1.2.4.

End-to-End logic of activities:

Technology maturation 2017-20

Subscale demos 2019-21

Application decision 2022-25

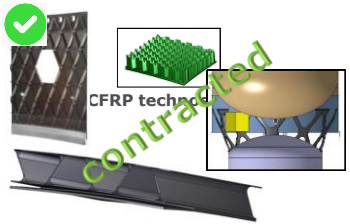
Full scale demo 2019-22

Upper Stage System (MUSE)

contracted

subscale CFRP tank (ComET)

Phase A/B1 contracted



CFRP techno

contracted

contracted

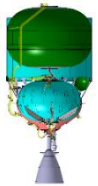
subscale ALU tank (SCOUT)

contracted

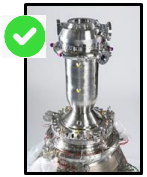
FPS & Avionics demo platform (LTIP)

PHOEBUS

Full Scale Mass & Functional Upper Stage Demo



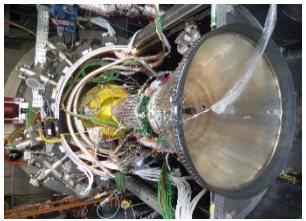
VINCI +



ETID

2- ETID / Vinci +

FLPP Programme Proposal §6.1.2.4.



2013-19
FLPP 3 - ETID
23 hot-fire tests
2,707 seconds
From **90 to 150 kN** tested
Mixture ratio from **4 to 7** tested

ALM injector head
NiCo jacket
Low cost copper liner
Optimised regen nozzle
Electronic regulation
Electric valves
Laser ignition
Spark ignition

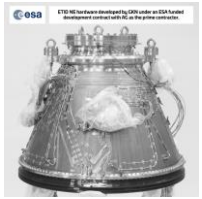
« ever lower cost, lower mass »

All CGS combustion chamber
ALM injector head
WAAM manifolds
Industrial laser or spark ign.
Low cost regen nozzle
Light weight CC/NE junction
Ultra light rad skirt

Low cost electric valves (ALM)
Flight design electronic regulation

Light weight turbopumps
AM turbines, AM manifolds, …

Light weight HP pipes



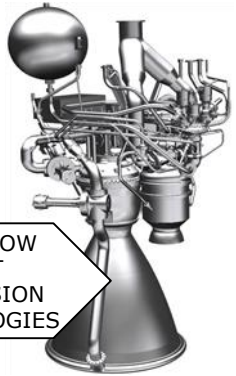
2019-23
ETID 2 / Vinci +

-50% on MASS

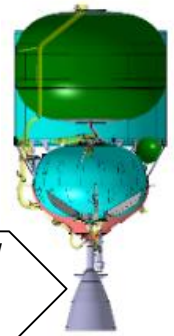
-50% on PROD COST

P4.1 – Tests at engine level

ETID / Vinci +	
Isp	**> 457 s**
Mass	**< 260 kg**
Thrust range	**110-150 kN**



ULTRA LOW COST PROPULSION TECHNOLOGIES

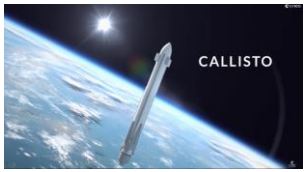


LIGHT & LOW COST PROPULSION SOLUTION

3-Prometheus & Themis

Preparation 2016-20

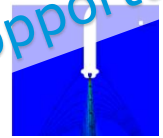
National & EU

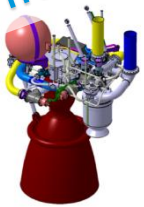


European Commission

ARIANEWORKS

ESA





Business opportunities

Flight test: 2023

Objective:
Protoflight recovery with Prometheus

Application

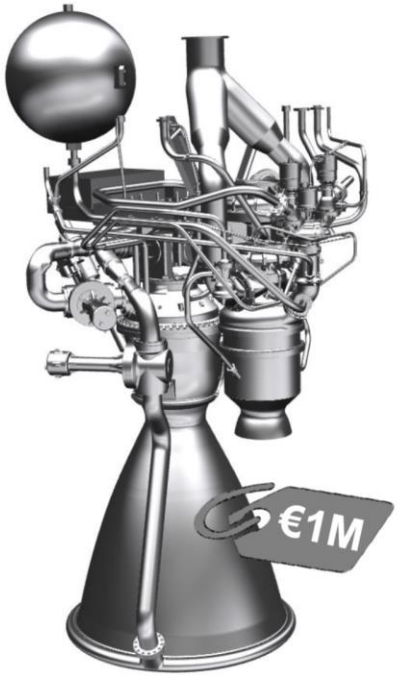
3- Prometheus Element

FLPP Prog. Prop. Section 6.2

Objectives

Target Ariane evolution (Vulcain Neo/Vinci+, main propulsion) as specified from FLPP System studies (Demo HLR) with validation of the following:

- Recurring Cost, target 1M€
- Versatility in terms of engine application, upgrade potential
- Thrust/weight ratio and delivered performances.
- Reusability.



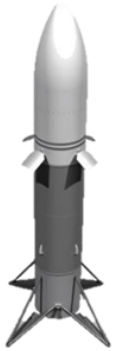
First Test Campaign by end 2020 at DLR Lampoldshausen (DE)

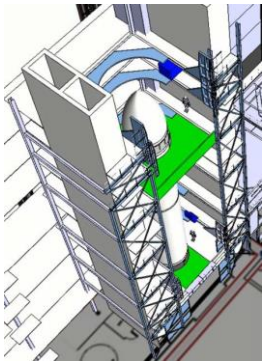
3-Themis/Reusability: Space19+

(FLPP Prog. Prop. Section 6.3)

Business opportunities

Activities:



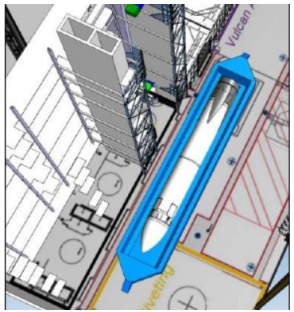


Flight Vehicle :

- Demo preliminary and detailed design
- Development logic and plan
- Vehicle manufacturing (2 configurations)
- Subsystems ground tests (tank functional tests, avionic & software tests, structural)

Ground segment:

- Selection of launch and recovery sites
- Design of launch and recovery means (or adaptation of existing ones if relevant)



Combined tests:

- Ground tests (including firing tests of the full demonstrator)
- Flight tests including refurbishments (~5)

FLPP: Business opportunities

VEGA C/Evo/VSS

Themis

Demonstrators

Kick-stage

Ariane 6 Evo/Next

Req

SRD's

Req

New Tech

Req

Space Logistics

Sandbox

Generic and Crosscutting Technologies

Technologies for Propulsion

Structures, dynamics, efficient integration

Advanced Avionics

Technology needs	Elements	Space Logistic element	Priority
GNC			
	Hybrid navigation using Galileo/GPS	All	1
	Atmospheric GNC	VegaC, A6Evolutions, microlauncher, flying test bench,...	1
	Orbital GNC including docking	All (docking : Moon ascent vehicle, Space Tug, Cargo, servicing vehicles)	1
	Moon landing, and ascent, Earth landing GNC	All Next reusable	1
	Reentry GNC	All Next reusable, Cargo reusable	1
Avionics			
	Inertial Measurement Unit	All	5
	Reaction Wheel	All	5
	Startracker	All orbital	3
	Sun Sensor	All orbital	3
	Earth Sensor	All orbital	3
	GPS	All	5
	Magnetotorquers	All	4
	TM/TC	All	5
	OBC	All	4
	Harness	All	4
	PCDU	All	5
Power			
	Solar panels and SADM	Venus, Kickstage, Space Tug, Depot, Servicing vehicles	5
	Battery	All	3

Business opportunities

TDE/GSTP

Other R&T

Highlights: business opportunities for Belgium

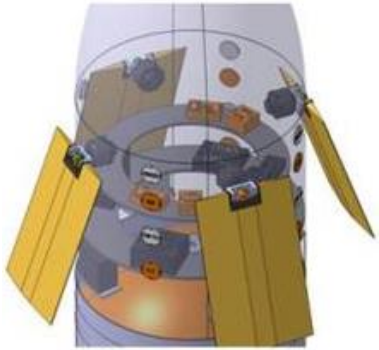
- Kick Stage subsystems and S/W
- Themis structures, Material, grid fins and actuator
- Valves for Prometheus/Themis
- Valves for Vinci+
- Valves for Vulcain Neo
- Valves for Berta Kick Stage
- Avionics, Battery and actuator, Electric propulsion elements
- Bearing tests for Prometheus and Vulcain Neo
- Aerodynamics for Themis testing
- Additive manufacturing for propulsion and structures
- …/…

For more details, see FLPP 4th July WS presentation and Programme Proposal

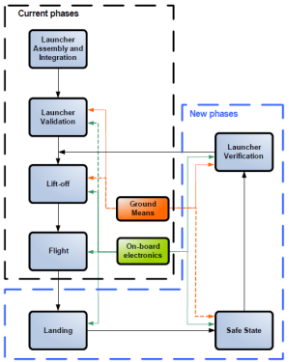
Some Belgium achievements

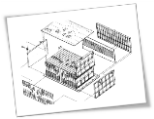
- Power-over-Ethernet Demonstrator

- CALLISTO mechanisms



- CALLISTO flight neutralisation and study of impact of reusability on avionics

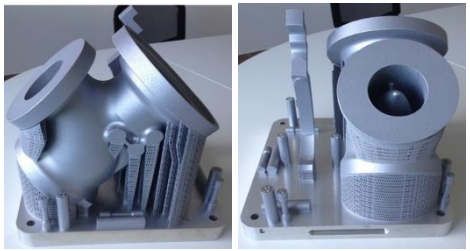




Cryogenic propulsion: Belgium achievements

- Belgium reached in FLPP the most advanced technological stage for cryogenic rocket engine valves in Europe
- In 2018-19, tests in full scale real hot-firing conditions of electronically controlled valves

- Rapid progress into low cost additive manufacturing processes for cryogenic valves



Additive manufacturing – optimised internal fluid veins

Figure 14 : Additive Manufacturing hollow ball

Cryogenic propulsion: Belgium achievements

- Belgium is **key provider** of valves for the Ariane cryogenic engines

- After compelling technological demonstrations in FLPP NEO, Belgium is ready to design and produce the valves for the next generation of European engines, i.e. Prometheus / Themis, VINCI +, VULCAIN NEO, in the upcoming propulsion projects of FLPP

- Belgium is well positioned to achieve the challenging objectives of serial cost reduction and electronic flow control assigned by the next generation of rocket engines in Europe

Why investing in future ST preparation?

A6 selection…

RUAG Space

Payload Fairing
Out-of-autoclave
Automated NDI

External Thermal Insulation

MT Aerospace

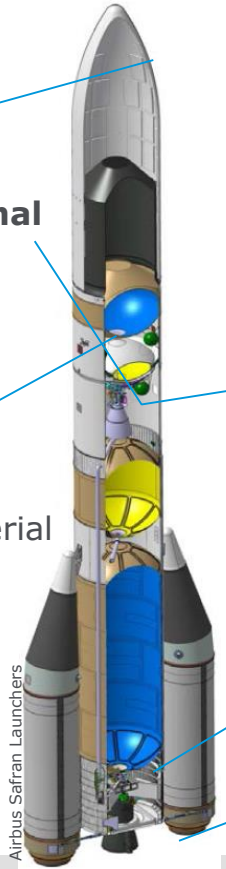
Advanced Friction Stir Welding
Al-Li base material

Opto-Pyro chain

ArianeGroup / CRISA / KDA

TTEthernet

TTTech



Airbus Safran Launchers

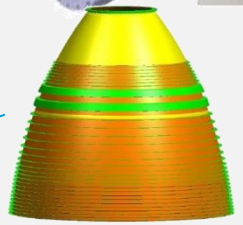
Additive Layer Manufacturing

Vinci Injector Plate
Direct Metal
Laser Sintering

ArianeGroup

Airbus Safran Launchers

Vulcain 2.1 Gas Generator
Direct Metal
Laser Sintering
Vulcain/Vinci
Valve
technology



GKN Aerospace

Vulcain 2.1 Sandwich Nozzle
Laser welding
Laser Metal Deposition

Back-up Slide

FLPP Programme Proposal:

To cope with these objectives, the flpp Programme Proposal is structured as follows:

1. Studies, Demonstrator and Advanced Technology **Core Element** incorporating:
   - **System Studies** including space logistics
   - **Advanced technologies**
   - Demonstrators:
     - **Kick Stage** + Green storable propulsion
     - **Upper Stage** Demonstrators
     - Subscale **reusability Roadmap**
     - **Avionics** Test Bed
2. **Prometheus Element** incorporating:
   - Prometheus engine phase 2 Demonstration
   - Application plan of Prometheus advancements to operational engines
3. **Themis/Reusability Element**

Core Technology bricks & studies

List of activities:

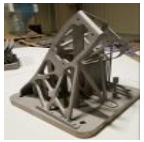
- *Technologies:* Implementation of Technology Roadmaps (All MS Industry)

Low cost propulsion
- Component technology maturation
- Throttling techniques
- Engine life prediction/monitoring
- Engine clustering
- Electric cycle techno bricks

Additive Manufacturing
- Fast printing and large print area
- Multi-material in one print
- Process standardisation
- NDI tools and methodology (e.g. on-line/in-line process repair strategies)

Advance Avionics
- Low cost low weight H/W
- Fault tolerant and autonomous systems
- GNC for re-entry and landing
- Wireless network
- Innovative telemetry
- Batteries (Li-S) and power generation

Digitalisation
- Virtual testing approach
- Industry 4.0
- AI application to Tests



Generic / Crosscutting technologies

Major axes of maturation work

Materials, Structures and mechanisms
- Advanced metal forming and joining
- CFRP technologies
- In line monitoring and testing
- Vibration control/payload comfort
- Cryogenic tanks and propellant mgnt
- Flight actuation and separation systems

Reusability (entry/descent/landing)
- Recovery and reuse concepts studies
- Deceleration systems (inflatable, deployable,…)
- Vehicle HMS and FDIR
- Verification tools and facilities
- Materials aspects on reuse

Advanced concepts/Skunk works
- New engine cycle studies
- Hypersonic and HAPS
- Air launch and drop systems
- Carbon nano-based composites
- Human rating, ISRU, …

Additive Manufacturing

Propulsion

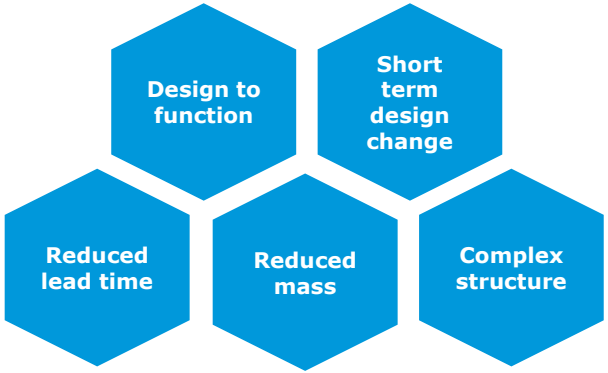
Small-scale combustion chamber and injector, ArianeGroup GmbH

Turbine manifold, GKN

All-in one injector, ArianeGroup GmbH

Valve cover, SAB

Hollow ball puppet, SAB



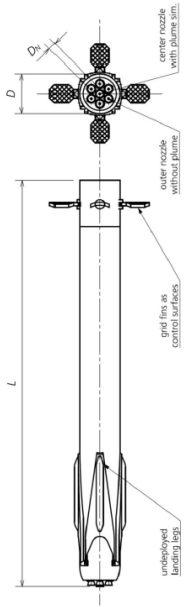
Structures

ISCAR bracket, ArianeGroup GmbH

Metallic PUSM bracket, RUAG

Polymer Vent-port RUAG

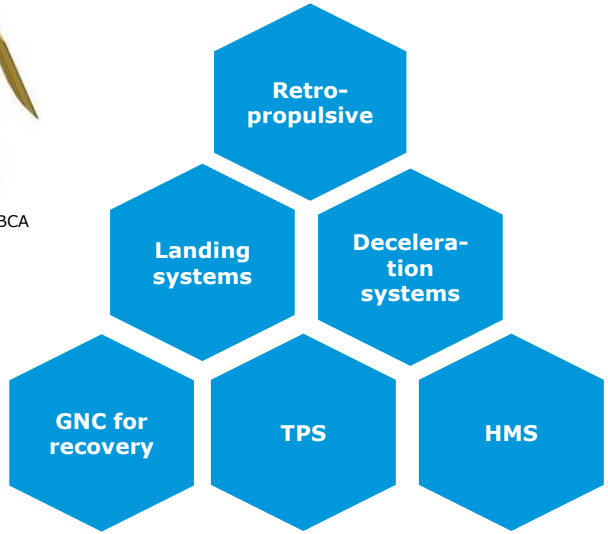
Reusability (entry, descent, landing, refurbish)



WTT and CFD for Retro-propulsion, DLR

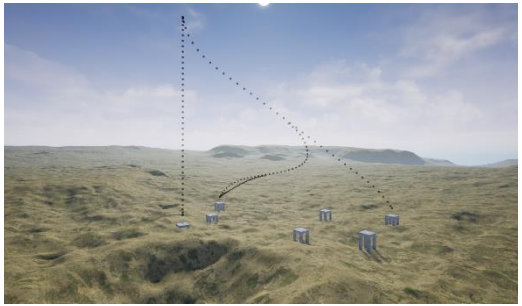
Fins Control System, SABCA

H2O2 Latch Valve, Nammo



DTV, INCAS

Micro-launcher 1st Stage recovery, PLD



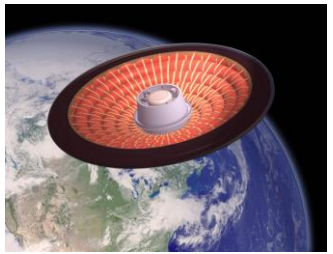
On-board real time trajectory guidance, Embotech

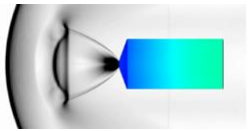
Reusability

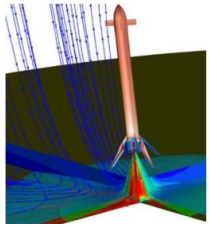
Space 19+ perspectives: Bricks for reusable Demo's and LV elements

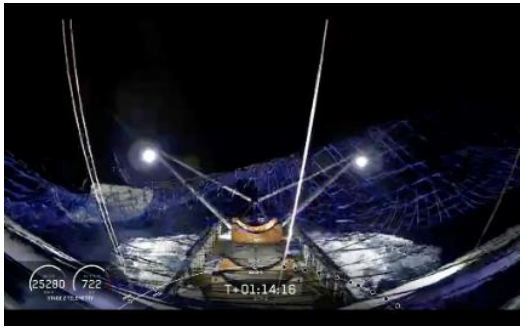
FLPP Programme Proposal § 6.1.3

- ❑ **Recovery and reuse concept studies**
- ❑ **Deceleration and recovery systems (inflatable,**
- ❑ **Vehicle and structures HMS and FDIR**
- ❑ **Reuse aspects on materials and avionics**
- ❑ **Propulsion techno's (throttling, clustering, etc)**
- ❑ **Verification tools and facilities**







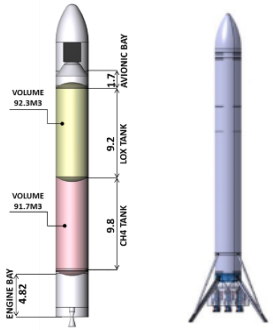


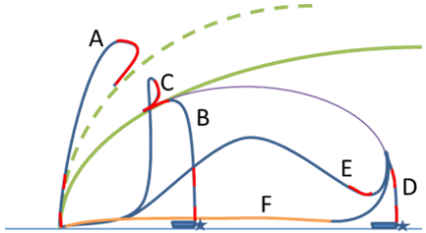
Reusability

Space 19+ perspectives: Specific technologies for retro-propulsive Liquid Reusable Booster/Core stage

FLPP Programme Proposal § 6.1.3

- ❑ GNC for recovery (hybrid nav, robust perf., autonomy)
- ❑ Multi Engine Bay TMF
- ❑ Landing legs
- ❑ Aerosurfaces/ re-entry stabilizers
- ❑ Health Monitoring System
- ❑ Rear Thermal Shield
- ❑ Reusable Thermal Protection System
- ❑ Autogenous pressurisation
- ❑ ACS





- ❑ **Advanced Avionics test platform**

Coordinated advanced avionics test bed, building on the technology maturation performed in Avionics domain focused on TRL increase for reusable in-flight Demo

Low cost propulsion

Space 19+ perspectives

FLPP Programme Proposal § 6.1.3

- ❑ **Electric regulation of engine**
- ❑ **Mixture ratio active regulation**
- ❑ **Engine life prediction/monitoring**
- ❑ **Boost pump**
- ❑ **Throttling techniques**
- ❑ **Low cost hybrid propulsion**
- ❑ **Electric components techno bricks**

Ariane 6 Competitiveness Improvement at Space 19+

Guy Pilchen

30/09/2019

Ariane 6 Competitiveness Improvement

The ESA **Council** adopted in April 2019 a Resolution stressing that … ***Ariane 64, Ariane 62 and Vega C … competitiveness needs to be further improved*** *with respect to ERKP and VEKP cost targets through industrial cost reductions and developments specifically geared towards increasing competitiveness.*

The PB-LAU in September approved unanimously the **creation of an Additional Slice** within the programme for Ariane and Vega development **for the Ariane 6, Vega and P120C Competitiveness Improvements**.

The **objectives** set for the Ariane 6 Competitiveness Improvement are:

- **2023 horizon objectives**
  - To achieve a launch service **cost reduction** of **10%** (w.r.t. ERKP reference)
  - To get a **performance increase** of 500kg GTO for Ariane 62
  - To develop a low-cost kick-stage based on extensive use of off-the-shelf components, taking the fast lane
- **2025 horizon objectives**
  - To achieve a launch service cost reduction of **20%** (w.r.t. ERKP reference)
  - To get an additional performance increase whose magnitude will depend on Future Upper Stage decisions to be made at Space19+ and CM22.

The cost reduction objectives are complemented by improvements system aimed at increasing its competitiveness on the market **extending the mission domain** and improving service to payload and payload environment.

The **development On Time**, On Cost, On Quality of the Ariane 6 vs its requirements **is a must**, and necessary before entering into improvement of the competiveness.

Ariane 6 Competitiveness Improvement

For Ariane 6 **Competitiveness Improvements activities**, the activities are driven by:

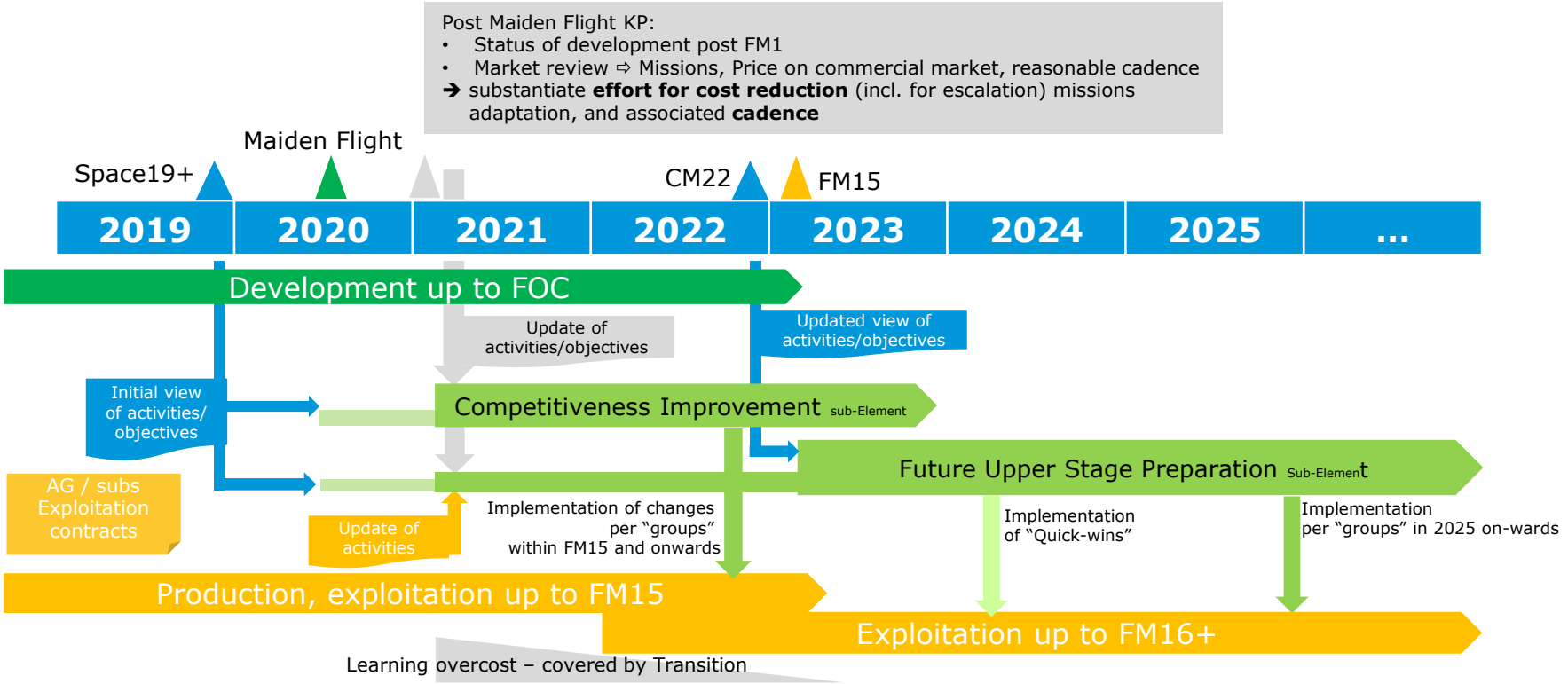
- **Cost reduction**, mainly achieved by i) Implementation of local launcher element definition changes, ii) modification of some manufacturing processes, and iii) improvement of launch campaign processes,
- **Improved performance**,
- **Multi-boost missions** with long coasting phases,
- **New missions** and injection strategies (also considering the kick-stage),
- Improved **Upper part flexibility** and P/L environment.

The cost benefit relation of the proposed activities will be assessed on the basis of the following elements:

- Cost reduction: cost reduction estimation over five years production / investment
- Improved versatility: Increased revenues estimated ex ante (increased number of launches per year) over five years / investment
- Improved performance: Increased revenues estimated ex ante (increased number of payload, improved filling ratio) over five years / investment

combining these elements, compared to thresholds built on a five years time horizon

Ariane 6 Competitiveness Improvement
Overall approach

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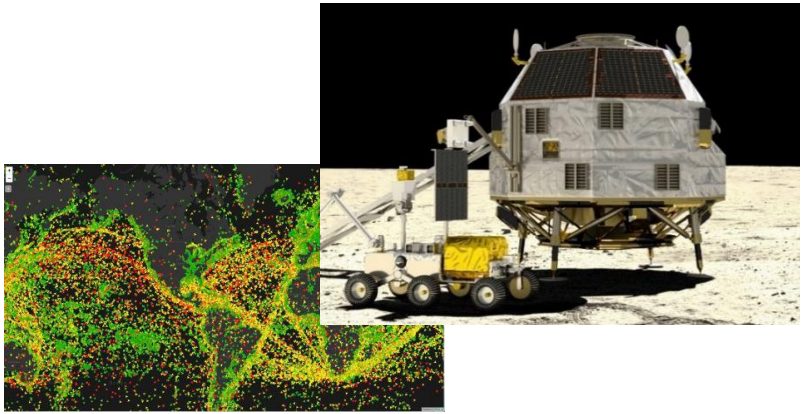
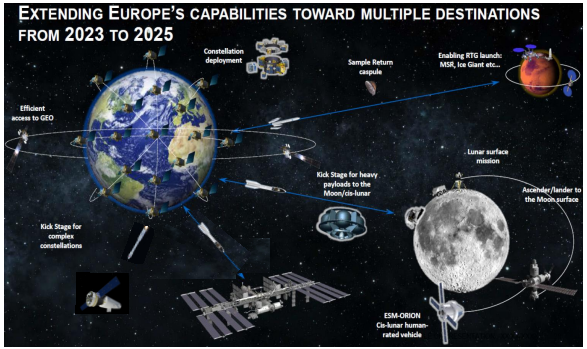
Conclusion
#Space19plus
Space19

Some words of conclusion





Space transportation more than just a lift

- End-to-end services, integrated in wider space business
- Intensification of interaction between commercial and institutional space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Thank you for your attention
Questions & Answers ?
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