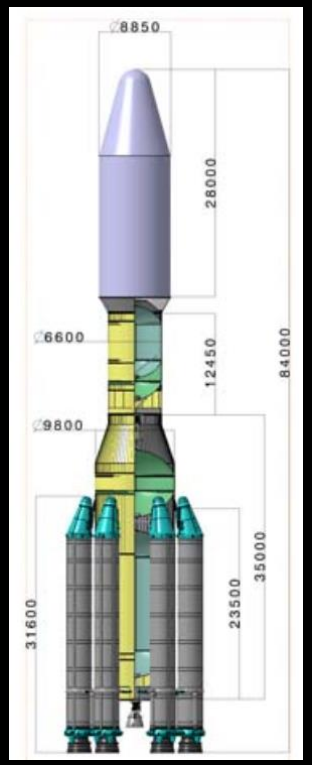
European Mars mission architecture using an enhanced Ariane launcher



Credit Ariane Group

Jean-Marc Salotti

Laboratoire de l'Intégration du Matériau au Système,

Bordeaux, France

and Association Planète Mars

Outline

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1. Ariane Super Heavy
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3. Crewed vehicle
4. Cargo1 to surface
5. Mars ascent vehicle (Cargo2)
6. Earth Return Vehicle
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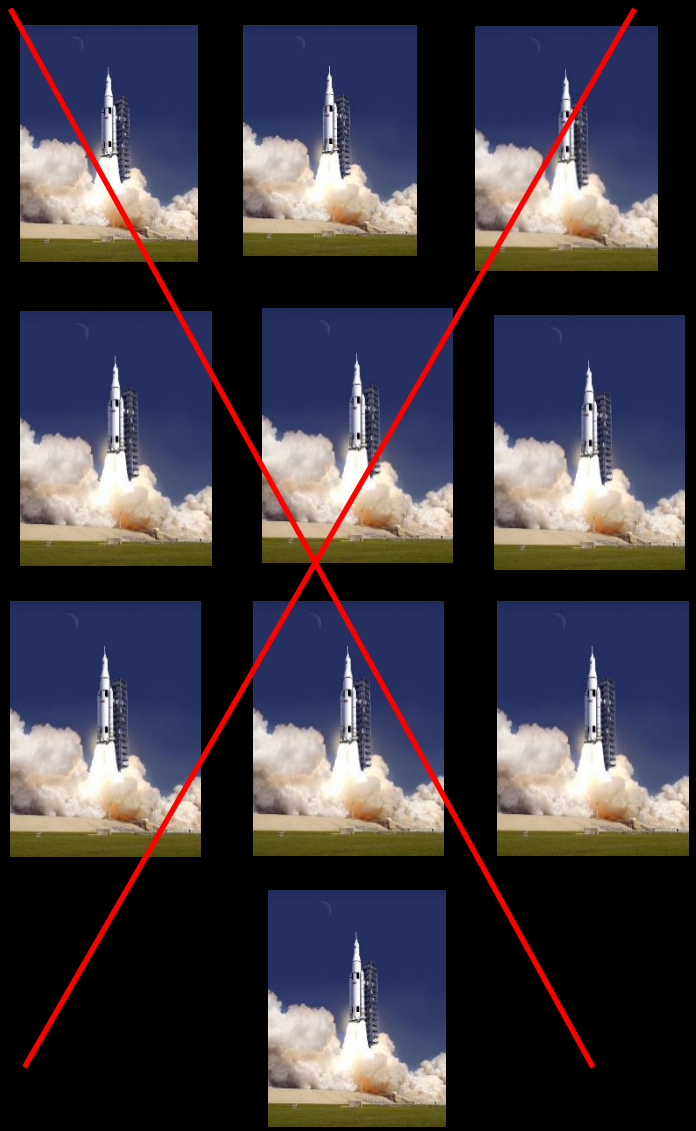
Introduction



Human mission to Mars:

- NASA: chemical propulsion => 1300 tonnes IMLEO => > 10 SLS ???

True but only if no aerocapture, 6 astronauts and giant spaceship construction.

=> NASA DRA 5.0 = unfair comparisons

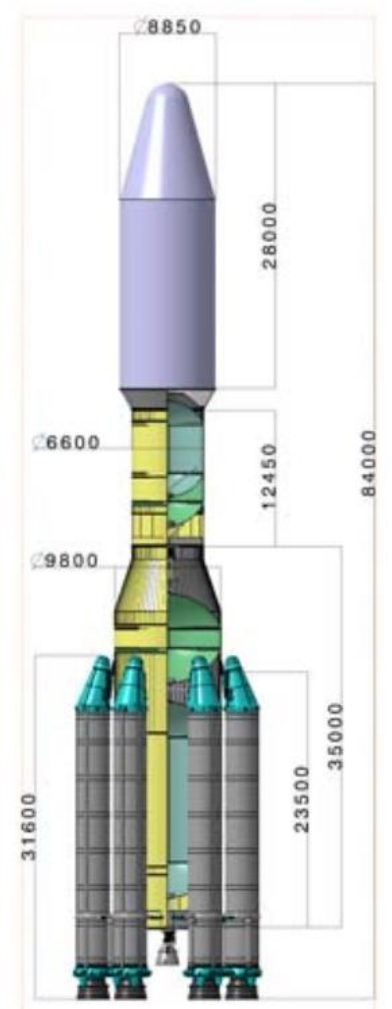
- Mars semi-direct, Zubrin :
  - Outbound: Direct to Mars surface
  - Inbound: MAV to Mars orbit before return to Earth
- Mars semi-direct with SLS, Salotti, Acta Astronautica, 2016: 520 tonnes IMLEO

What if Europe would like to go?

2006 study: Ariane Super Heavy

LEO capability:100 tonnes.

1. Ariane Super Heavy



Credit Ariane Group

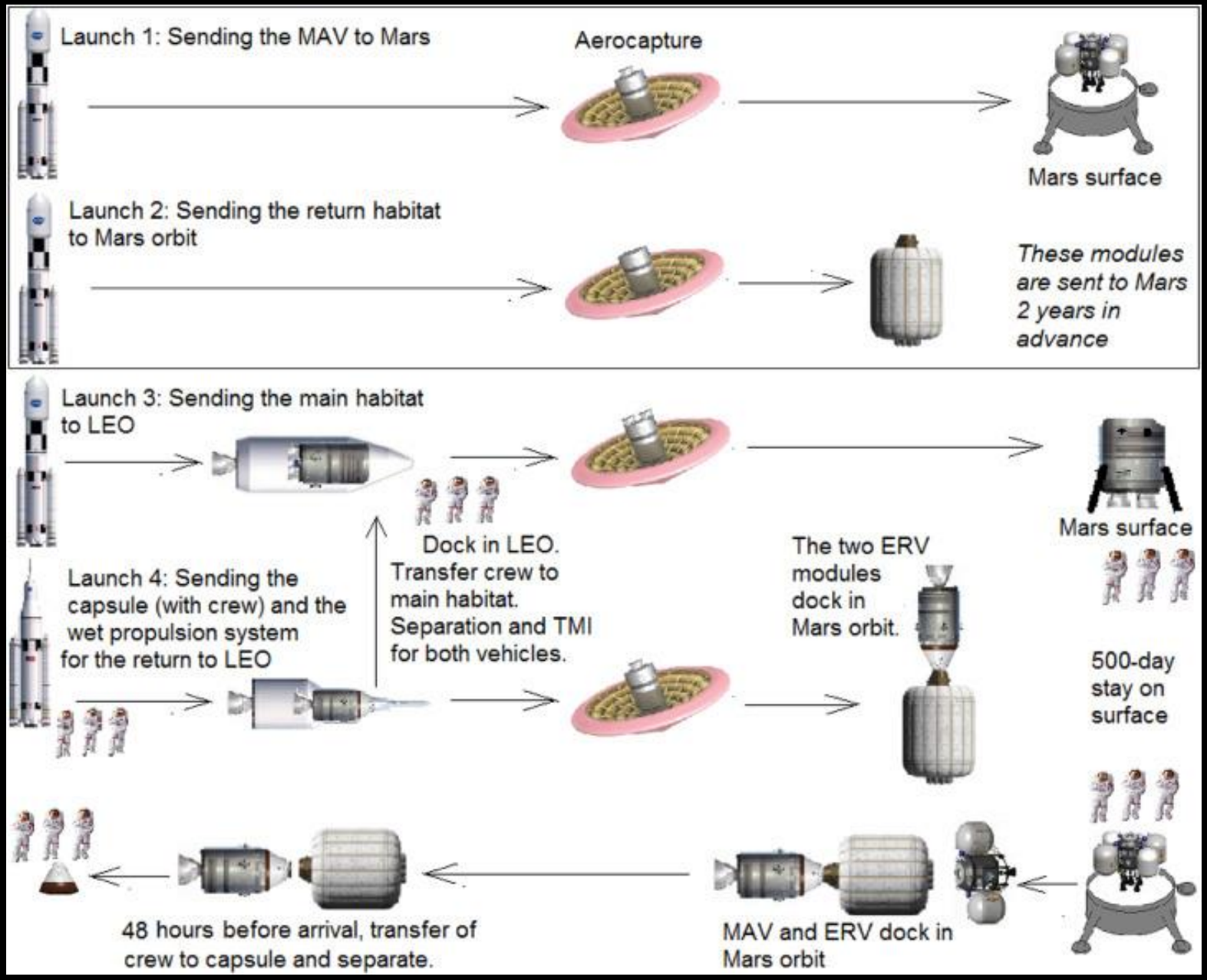
Height: 84 meters
First stage: 5 Vulcain II
6 Solid Boosters

Second stage: 1 Vulcain II

LEO capability: 100 tonnes
To Mars, TMI capability: **36 tonnes**

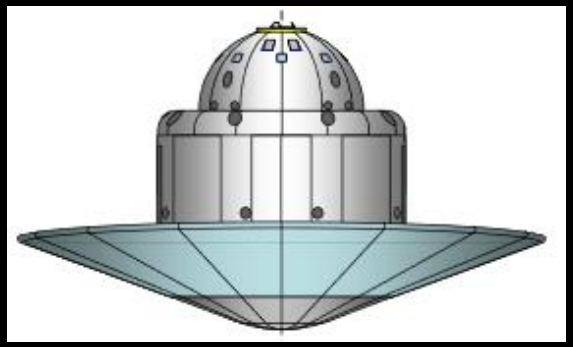
Reference: D. Iranzo-Greus C. Chavagnac, C. Talbot, J. N. Couteau, J. M. Conrardy, The European launcher option for exploration, proceedings of the International Astronautical Congress, IAC-06-D2.7./A3.7.07, Valencia, Spain, 2006.

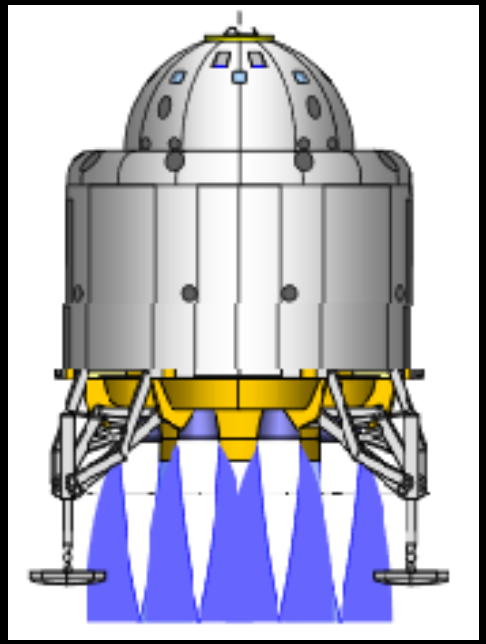
2. Mars semi-direct architecture



First proposal: Zubrin 1993.
J.M. Salotti, Robust, affordable, semi-direct Mars mission, Acta Astronautica, 2016.

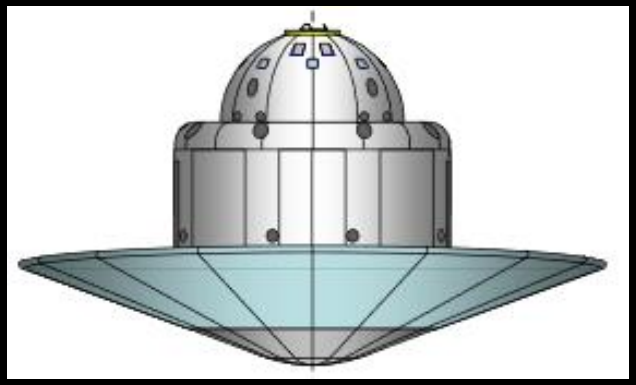
3. Crewed vehicle

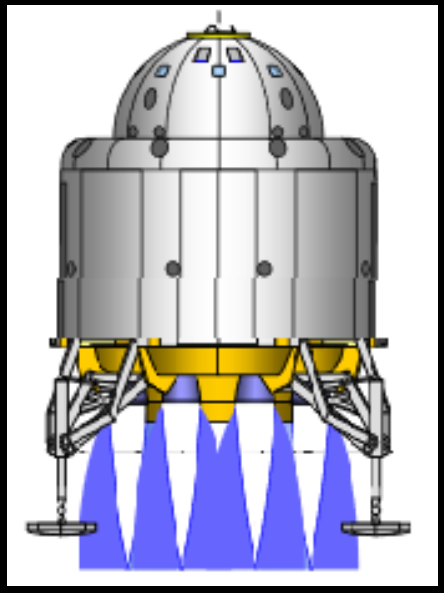




		Kg
Payload to the surface: Mars habitat.	<8 months trajectory, habitable module for 3 astronauts, **250 days life support** (extrapolated from NASA study)	17691
TOTAL payload mass		17691
Aerocapture and EDL systems	**Deployable 14 meters diameter rigid heat shield; dual use aerocapture and EDL**	
	+TPS and backshell	
	+Avionics and separation structure	
	+RCS dry mass (propulsion system for circularization and descent control)	
	+Propellant for RCS propulsion system, circularization burn for Mars orbit insertion, then descent control	
	+Descent stage, propulsion system and landing legs, dry mass	
	+Descent stage, propellant	17691
TOTAL EDL SYSTEMS (50% of total)		17691
TOTAL		**35382**

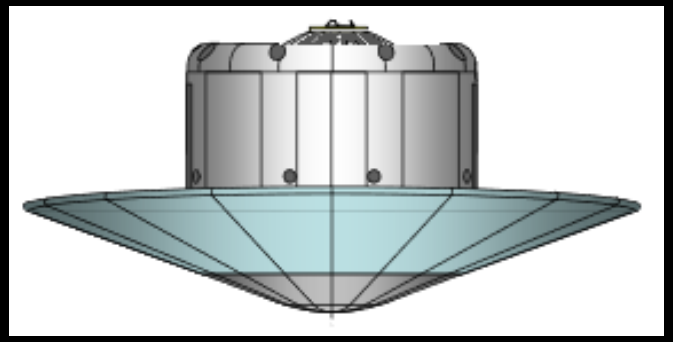
4. Cargo1 to surface





		kg
Payload to the surface: Cargo vehicle.	500 days life support consumables	8000
	Other consumables	2000
	Power systems	2000
	Rovers and rovers consumables	2000
	Scientific tools	2000
	Structure	1000
	TOTAL payload mass	17000
Aerocapture and EDL systems	Deployable 14 meters diameter rigid heat shield; dual use aerocapture and EDL Etc. TOTAL EDL SYSTEMS (50% of total)	17000
TOTAL		34000

5. Mars ascent vehicle (cargo2)

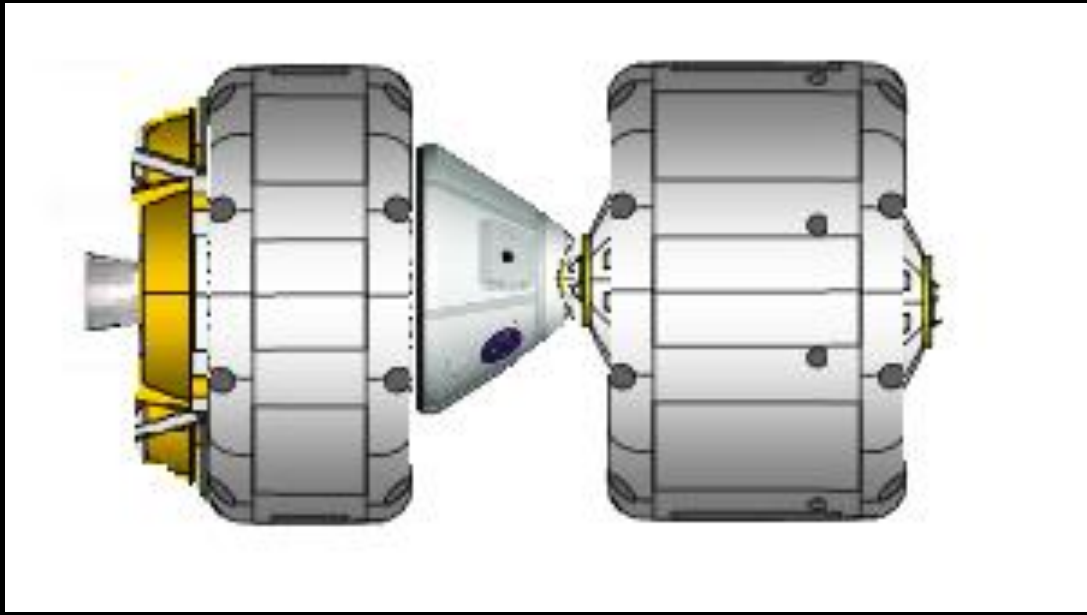


			kg
Payload to the surface: Mars ascent vehicle for 3 astronauts **(Extrapolation from NASA Mars Ascent Vehicle concept, DRA 5.0, 2014)**	1st stage	Inert mass	2557
		Propellant: LOX	**0**
		Propellant: LCH4	1925
		Total	4483
	2nd stage	Inert mass (including habitat module)	4907
		Propellant: LOX	**0**
		Propellant: LCH4	2181
		Total	7089
	Total MAV		11571
ISRU	ISRU systems (NASA data)		945
	Surface power systems		4000
	Deployment systems		300
Structure			1000
TOTAL payload mass			17817
TOTAL EDL SYSTEMS (50% of total)			17817
(Lucky) TOTAL			35634

6. Earth Return Vehicle

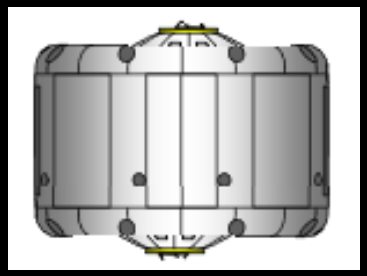
Part1: Propulsion system + capsule

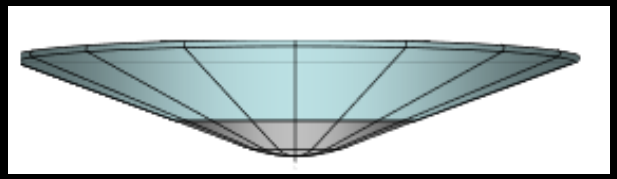
Part2: Interplanetary habitable module



MAV

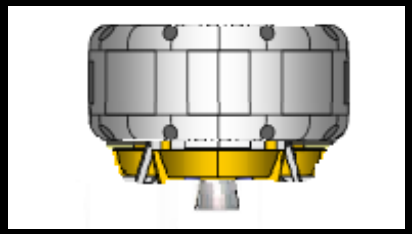
6.1 ERV1

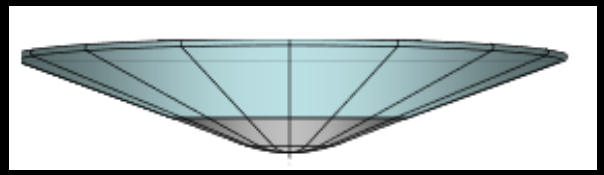




		kg
Payload to Mars orbit: ERV habitable module	Habitable module 3 astronauts **600 days life support** Abort to Mars orbit capability!	23496
Aerocapture and RCS systems	Deployable 14 meters diameter rigid heat shield	5000
	TPS and backshell	1500
	Avionics and separation structure	1000
	Propulsion for post-aerocapture burn, attitude control and Mars orbit rendezvous, RCS dry mass	500
	Propulsion for post-aerocapture burn, attitude control and Mars orbit rendezvous, RCS propellant	3000
	Margins	1000
	TOTAL AEROCAP. SYSTEMS	12000
TOTAL		35496

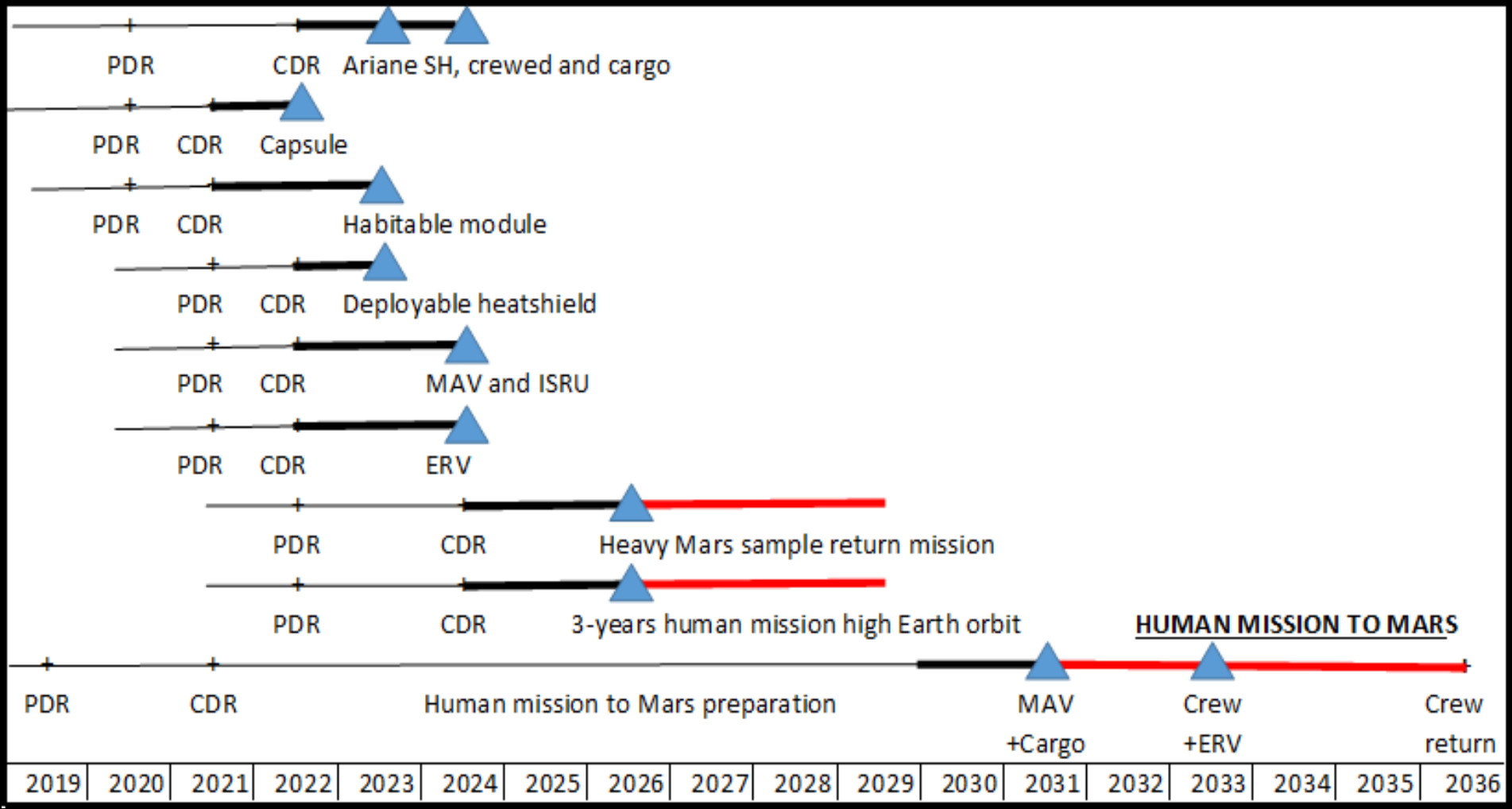
6.2 ERV2





		kg
Payload to Mars orbit: Earth reentry capsule.	Capsule	5000
	Capsule consumables	1000
	Structure, fixations to propulsion stage and separation mechanisms	1000
	Total Earth reentry capsule	7000
Payload to Mars orbit: ERV propulsion system, Delta V: 1.5 km/s	Propulsion stage dry mass	2000
	Propulsion stage, propellant CH4+O2 Total propel. mass fraction: 38%	13700
	Total propulsion stage	15700
Aerocapture and RCS systems	Deployable 14 meters diameter rigid heat shield Etc.	
	TOTAL AEROCAP. SYSTEMS	12000
TOTAL		34700

7. Possible roadmap



Conclusion

- Ariane Super Heavy: based on existing engines and boosters => relatively fast and cheap developments
- Aerocapture + 3 astronauts => payload optimization => direct to Mars possible within 36 tonnes TMI constraint
- 14m deployable rigid heat shields = most simple EDL systems
- 5 equal payload masses => simplified tests and qualifications
- Simple roadmap

=> Total cost < 100 b. Euros

SLS and Ariane Super Heavy = similar LEO capability

=> Possible use of different launchers = more flexibility and reduced costs

=> Human mission to Mars affordable for Europe!

Conclusion: affordable mission! < 100 b. Euros, 12-15 years preparation