Earth Entry Vehicle Design for Sample Return Missions Using M-SAPE

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Multi-Mission System Analysis for Planetary EDL (M-SAPE)

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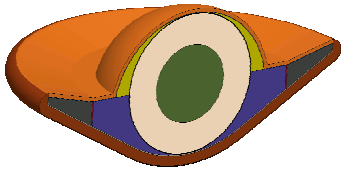
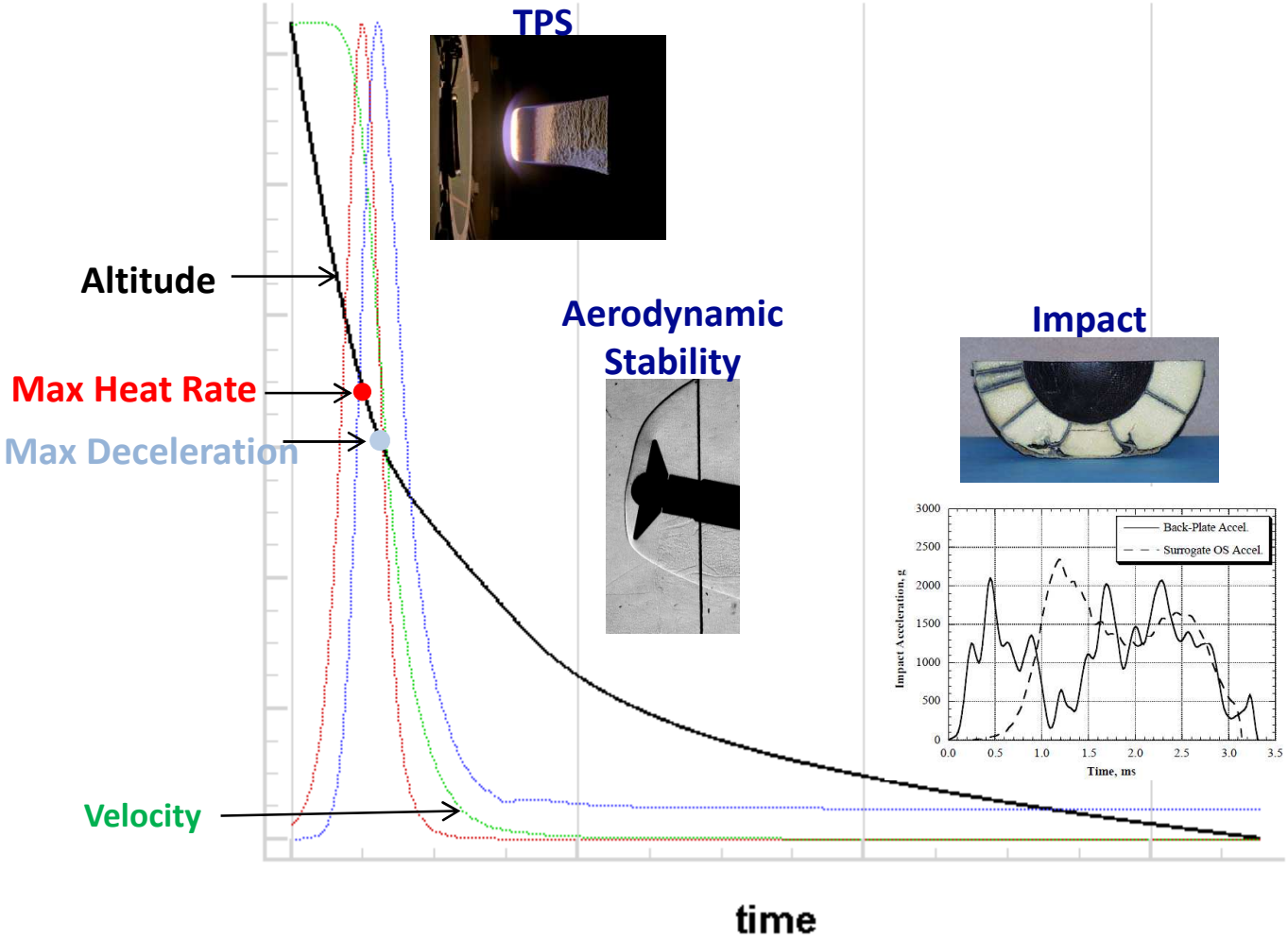
M-SAPE
(Summary)

- **What:** It is an integrated system analysis tool for analyzing and sizing of Earth entry vehicles for sample return mission applications.
- **Acronym:** **M**ulti-Mission Earth Entry Vehicle **S**ystem **A**nalysis for **P**lanetary **EDL**
- **Who:** LaRC, ARC, Virginia Tech, & Old Dominion University.
- **Disciplines:** Aero, aerothermal, flight mechanics, impact analysis, structure, thermal soak, TPS, …
- **Funding:** The In-Space Propulsion Technology Program (ISPT) & ESM.
- **Status:** Version 1 is complete.
- **Future Plan:** Currently developing a similar system for human Mars mission.

M-SAPE
(Earth Entry Vehicle EDL Environment)



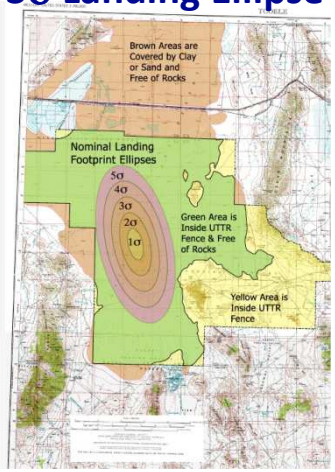


TPS

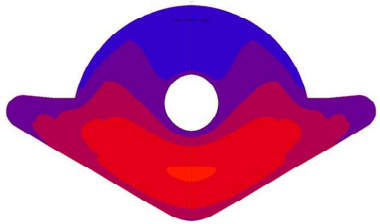
Aerodynamic Stability

Impact

3σ Landing Ellipse

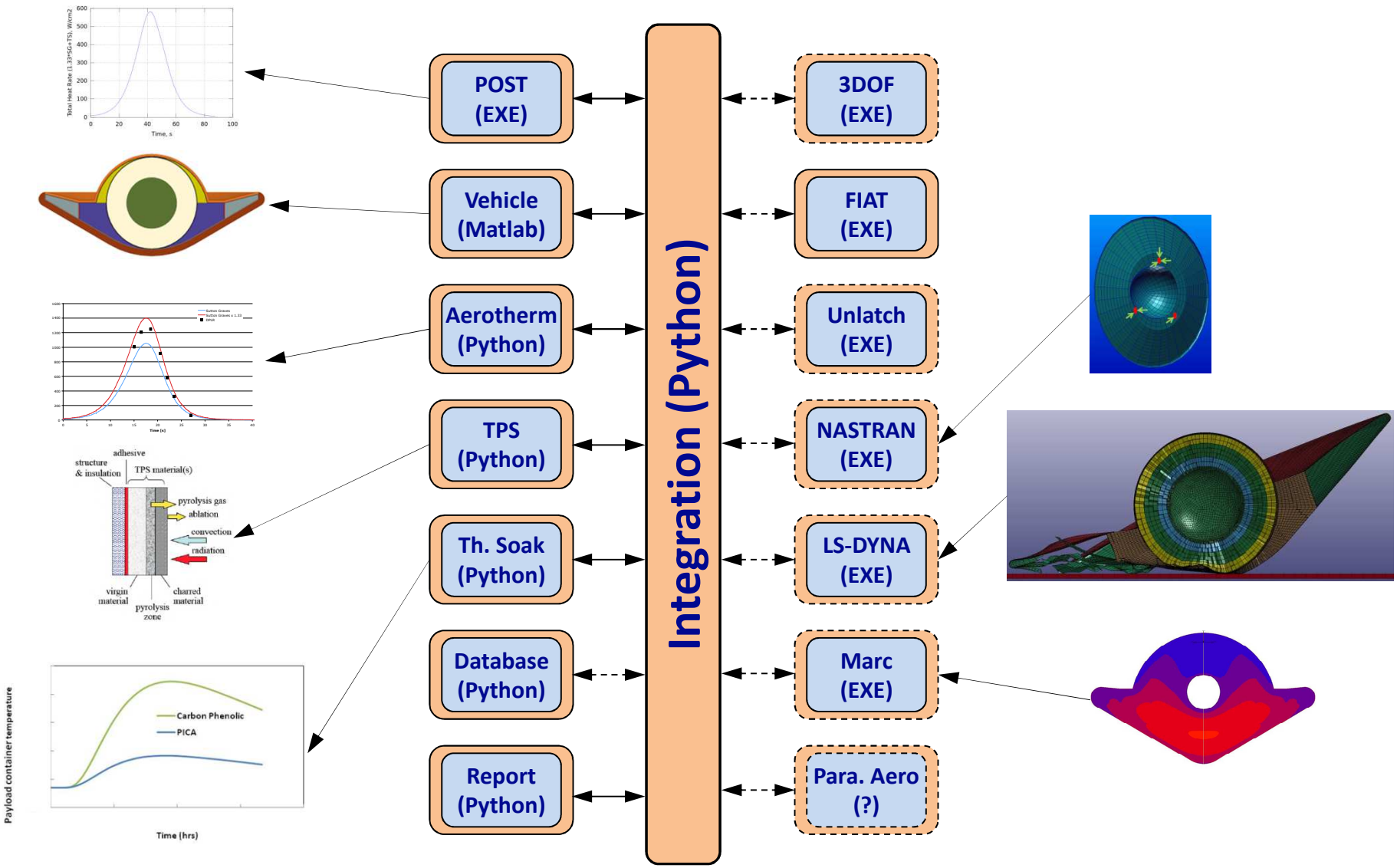


Thermal Soak



M-SAPE

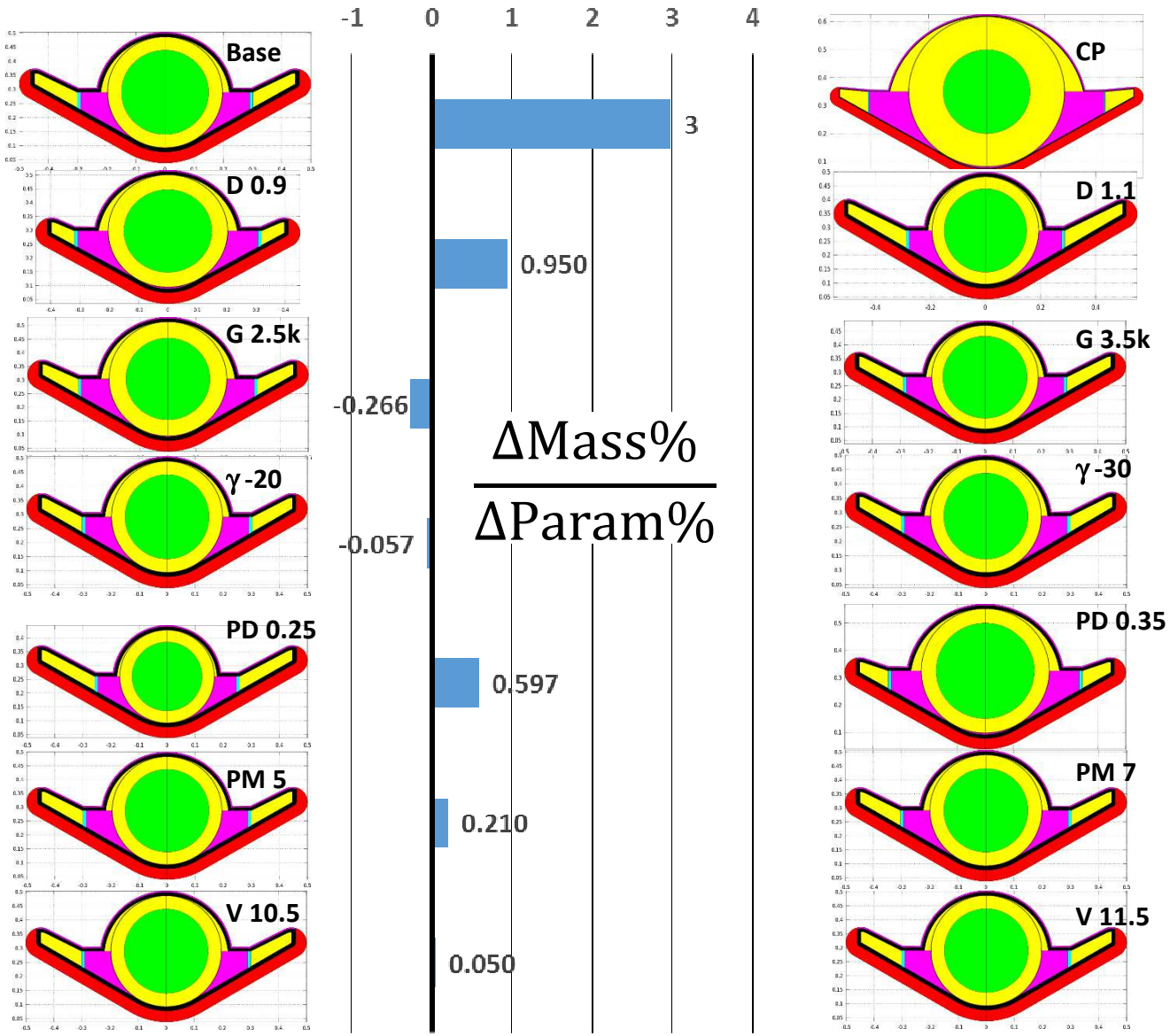
(Integration, Mission Dependent)



Vehicle Sensitivities

Case Name	D-1.0-B	CP	ΔDiameter		ΔCrush Load		ΔFlight Path Angle		ΔPayload Diameter		ΔPayload Mass		ΔEntry Velocity	
Vehicle Diameter (m)	1	1.08	0.9	1.1	1	1	1	1	1	1	1	1	1	1
Crush Load Limit (Earth k g's)	3	3	3	3	2.5	3.5	3	3	3	3	3	3	3	3
Entry FPA (deg)	-25	-25	-25	-25	-25	-25	-20	-30	-25	-25	-25	-25	-25	-25
Payload Diameter (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.25	0.35	0.3	0.3	0.3	0.3
Payload Mass (kg)	6	6	6	6	6	6	6	6	6	6	5	7	6	6
Entry Velocity (km/s)	11	11	11	11	11	11	11	11	11	11	11	11	10.5	11.5
Aerodynamic Stability	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Max Heat Rate (W/cm2)	918	1452	1027	840	944	903	826	995	879	972	901	934	776	1107
Forebody TPS Mass (kg)	13.9	64.0	11.5	16.5	14.0	13.8	14.3	13.6	13.8	14.1	13.8	13.9	13.8	14.0
Total Heat Load (kJ/cm2)	7.6	12.5	8.5	6.9	7.8	7.5	8.4	7.0	7.2	8.1	7.4	7.7	6.8	8.5
Max Payload Temp. (C)	18	45	17	18	18	18	18	17	18	18	18	18	18	18
Total Entry Mass (kg)	36.5	108.6	33.6	40.6	38.6	35.4	37.0	36.2	33.6	40.9	35.2	37.8	36.4	36.6
ΔMass% / ΔP%		3		0.95		-0.27		-0.06		0.60		0.21		0.05

Vehicle Sensitivities (Cont.)



Concluding Remarks

- The current version of M-SAPE was used to perform system analysis and sensitivity analysis of an Earth entry vehicle for sample return missions.
- For the sample baseline design:
  - Selection of TPS concept has the most impact on the design.
  - Vehicle size may be dictated by the required aerodynamic stability.
  - Higher payload diameter and mass result in heavier vehicles.
  - Lower impact g-load would result in heavier vehicles.
  - Entry flight path angle and velocity have less impact on mass compared to other parameters.