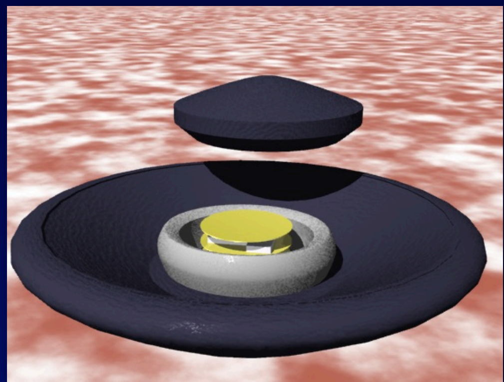
High-Speed Compact Sample Return Capsule enhanced by Lightweight Ablator and Chuteless Design



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Future High-Speed Entry Missions

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021

in Phase-B

Torojan Asteroids SRC

15 km/s ~ (2021?)

Hayabusa SRC
Heritage ~12km/s

High-Energy and long-term missions

Hayabusa-2

SRC ~ 12 km/s

June 13, 2010
Returned

Dec. 2014
Launch

June 2018
Asteroid Arrival

Dec. 2020
Return

Objective of the Research

For Realizing High-speed Entry Missions

Development of Compact Capsule should be done

1) In the Extremely Severe Flight Environment (~15 km/s),

2) to Secure the long-term Mission Reliability

↓ **namely**

- **Lightweight Ablator for Low Ballistic Coeff.**
- **Chute-less Landing by Crushable Material.**

*** Low Ballistic Coeff. is advantageous for reducing Max. Heatflux**

Chute-less landing avoids Loss of Mission

Desirable from Landing Dispersion Perspective

→ Present Research Status and Design Example

Flight Environment Consideration

The smaller Area and Noze Radius, the Lower Heatflux.

Φ50mm, Rn=0.22 => Heatflux same as Hayabusa SRC.

※ Effect of Conv. Heat flux Reduction exceeds Increase in Rad. Heatflux.

V=14.8 km/s. FPA=-10.3 ° (Shallowest within a limitation of Skip-out)

	Rn=0.20m	0.22	0.24	0.25
$S=0.12\ m^2$ (Φ40cm)	20.4	19.9	19.5	19.3
$S=0.14\ m^2$	18.9	18.5	18.0	17.8
$S=0.16\ m^2$	17.7	17.3	16.8	16.7
$S=0.18\ m^2$	16.7	16.2	15.8	15.7
$S=0.20\ m^2$ (Φ50cm)	15.8	15.4	15.0	14.8
$S=0.22\ m^2$	15.0	14.7	14.2	14.1

Advantage of 3D woven Ablator

- **it can avoid delamination due to release of Pyro-Gas Pressure along fiber bundles**
- **relatively low heat conduction in Z-direction**

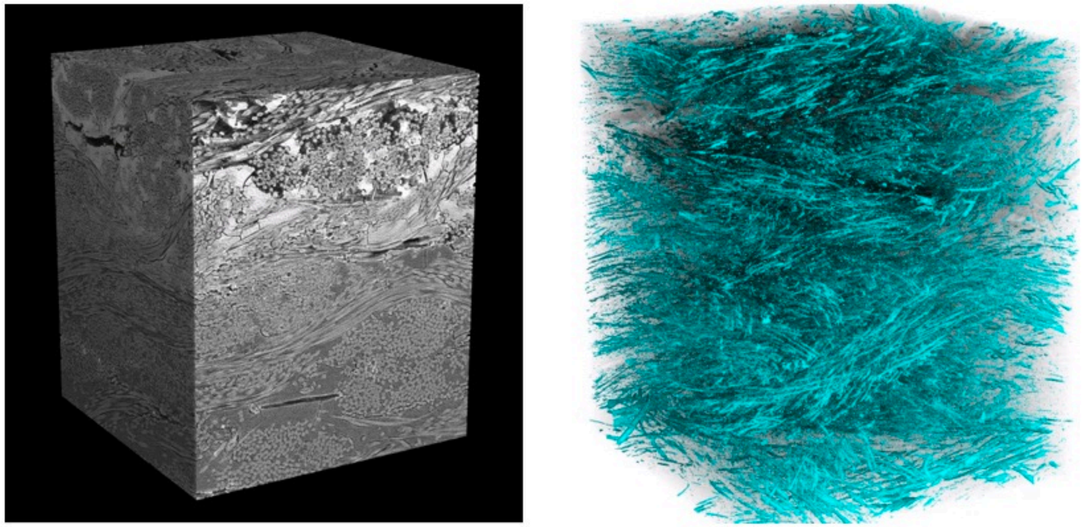


Fig. 3 Distribution of the closed-pore in the pyrolysis layer in the cloth-layered ablator (Image processed from 3-D X-ray tomography data taken in SPring-8)

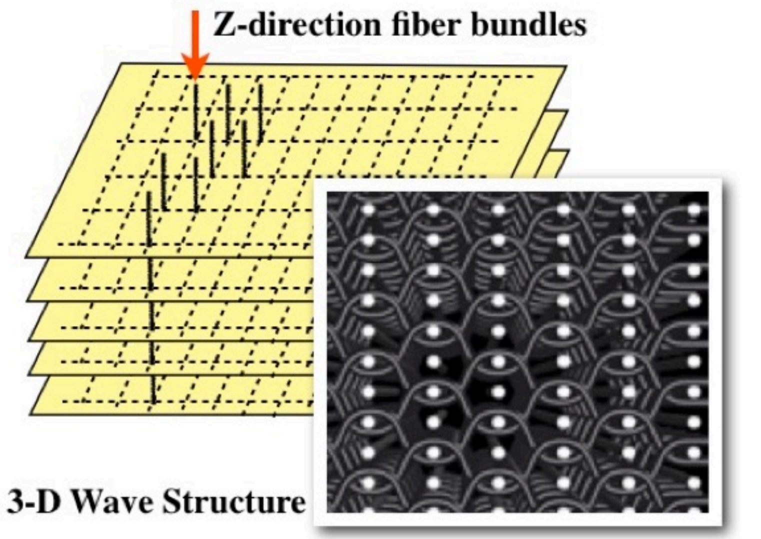


Fig. 4 : Schematic view of the conventional 3-dimensional ablator and the 3-D woven (3-D wave-structure) lightweight ablator.

3D woven Lightweight Ablator

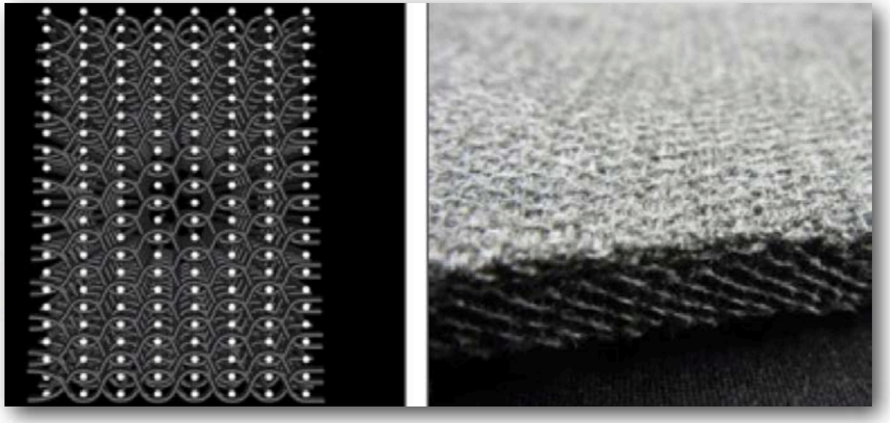
Design Target

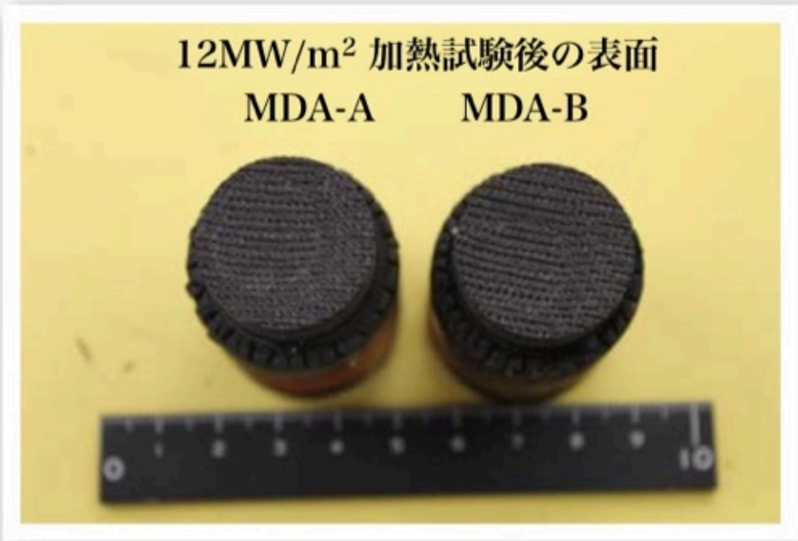
- High Allowable Stress both in-plane, out-plane
- Lightweight
- Delamination Countermeasure

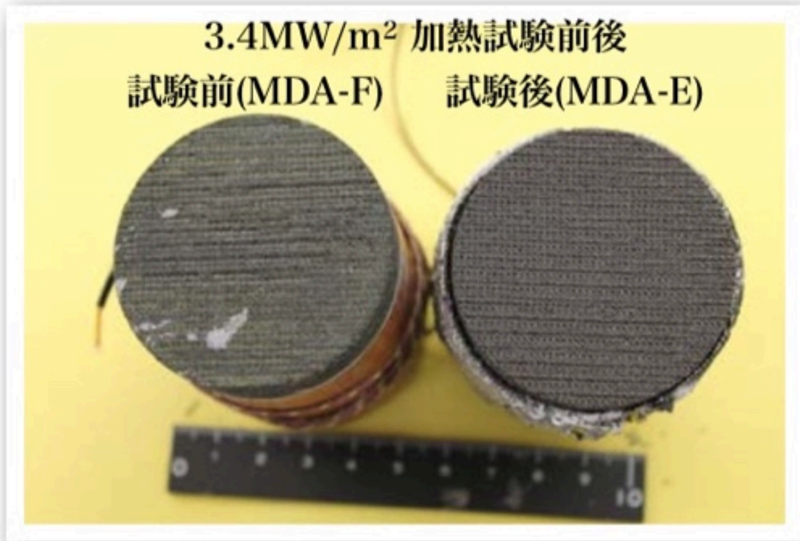
Result

Density : 0.47 g/cc 35% of Hayabusa H/S

Surface Recession : 0.12 mm/s @12 MW/m^2



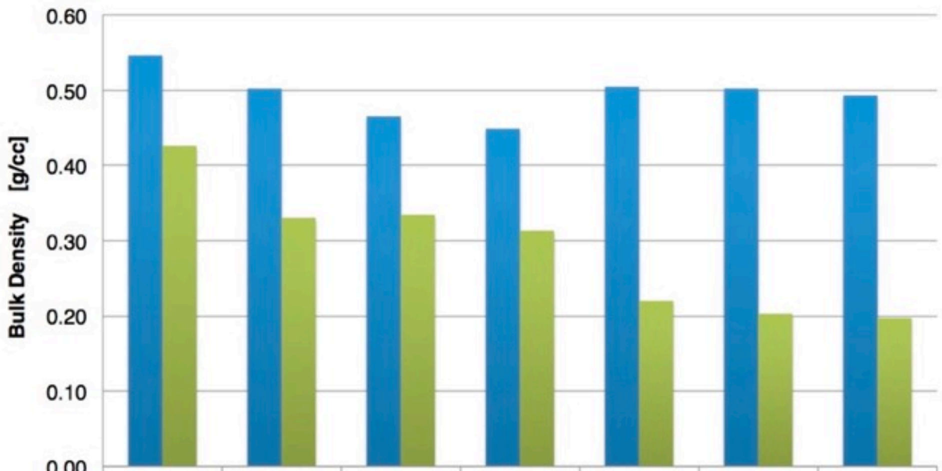




Performance of 3D lightweight Ablator

Density controllable by addition of lightweight Fiber bundles,
which melt-down and disappear after processing

No Delamination observed and Low Recessionin 12 MW/m² heatflux : 0.12 mm/s



	A : 100 %	A : 80 % B : 20 %	A : 70 % B : 30 %	A : 60 % B : 40 %	A : 80 % C : 20 %	A : 70 % C : 30 %	A : 60 % C : 40 %
Woven	0.55	0.50	0.47	0.45	0.50	0.50	0.49
Cured	0.43	0.33	0.33	0.31	0.22	0.20	0.20

Fig. 5 Thermal properties of the 3-dimensionally woven ablator.

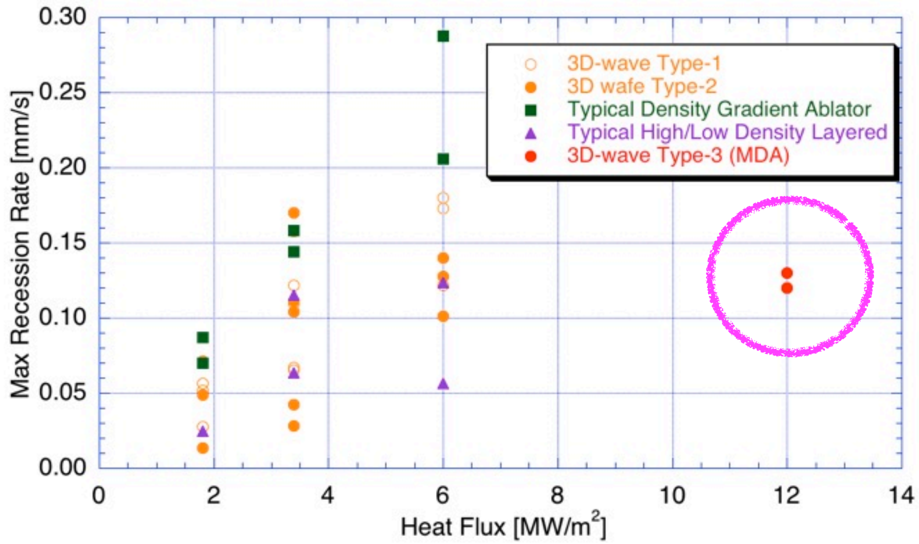
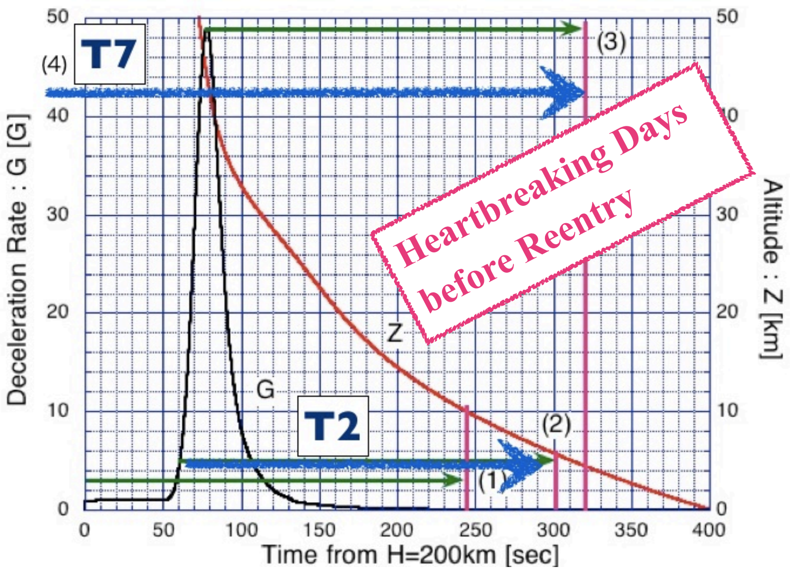


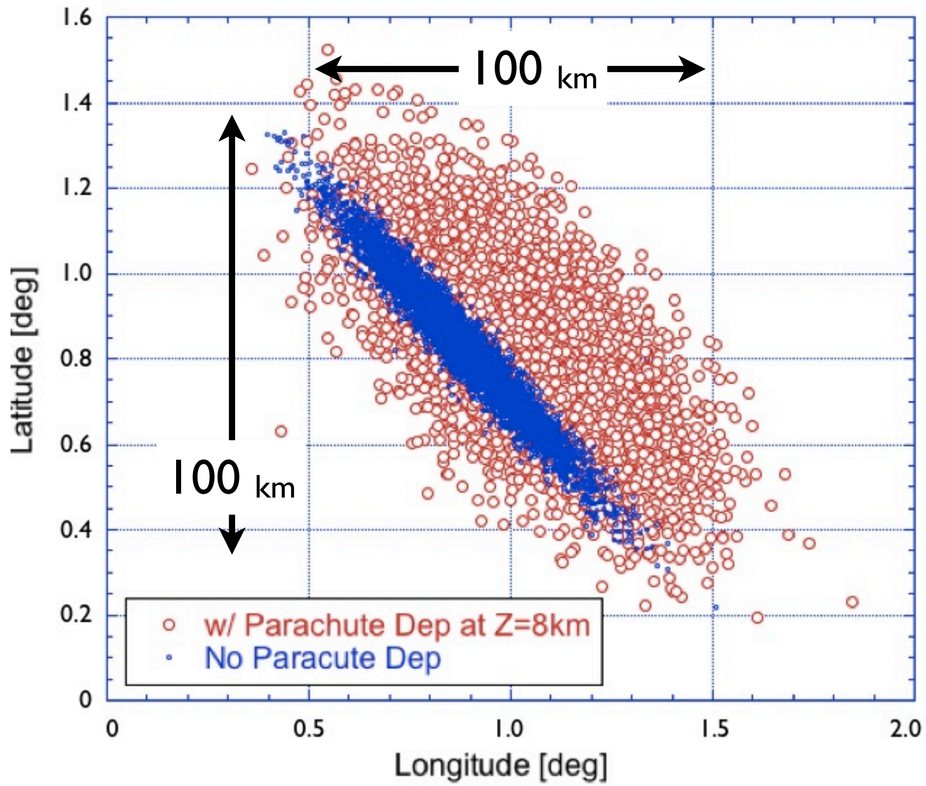
Fig. 7 Recession Characteristics with paratmeters of the heatflux.

Merit and Issues of Chuteless Design

Merit

1) it can avoid Loss of Mission (when properly designed) due to malfunctions during Orbital Flight.
2) Small Landing Dispersion due to Small Wind Effects
3) Chute-Descent Sys. No-longer Required :
   Chute, Timers, G-Sensors, Pyrotech. Devises, BATs, FPGA





Issues

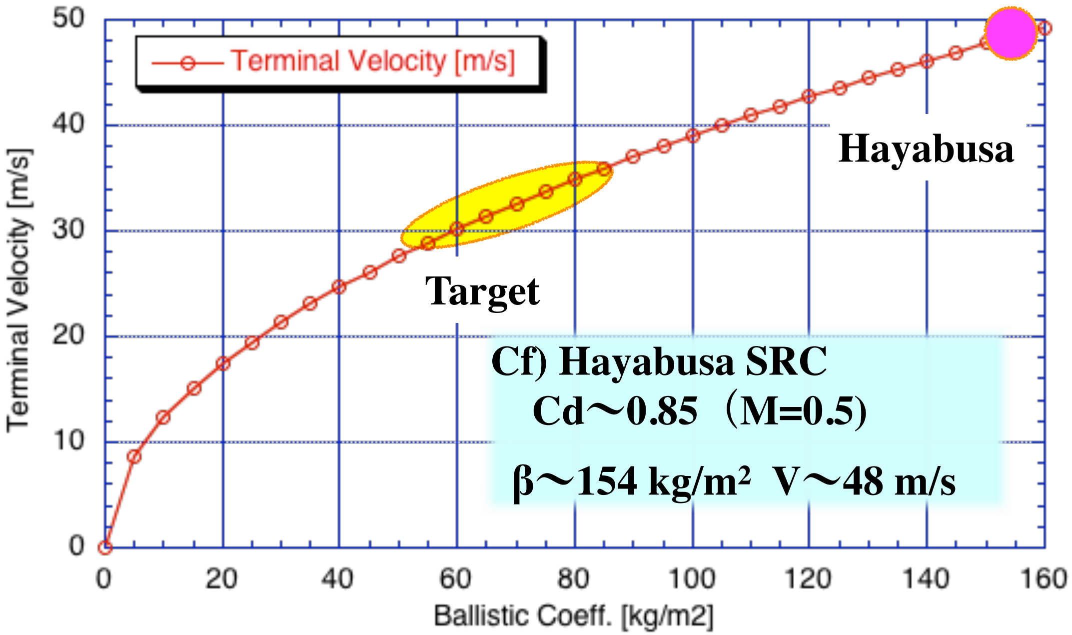
1) Subsonic Stability
2) Material Selection and Tests

Crushable Test Model (Crushable Ball)

Terminal Velocity ranges

30-40 m/s

according to Ballist. Coeff.



Acc. Limit for Instrument be

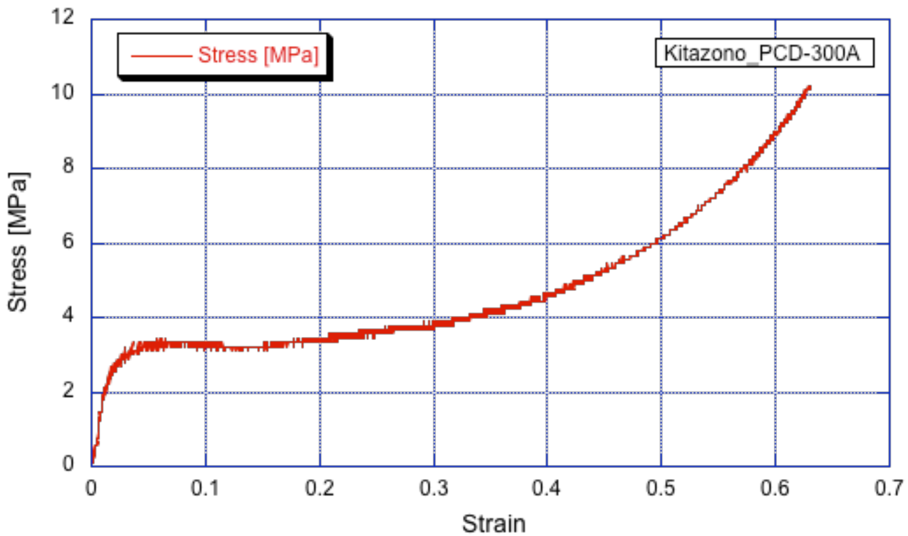
< 3,000 G

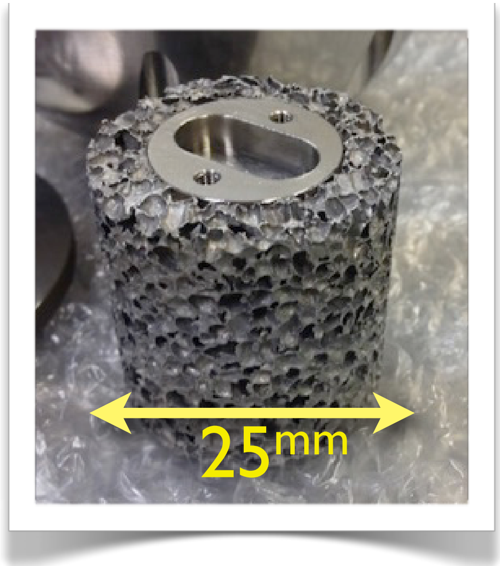
to restrain Landing G below 3,000

Cellular Metal

$\sigma_p : 2 \sim 3MPa$

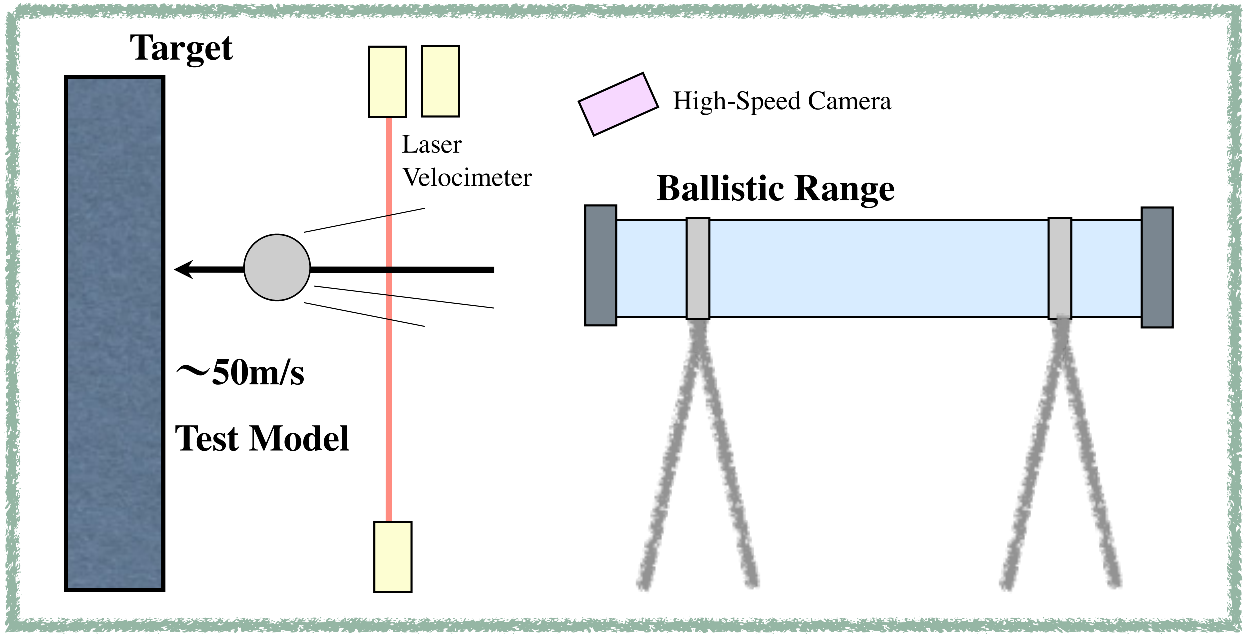
$\varepsilon_2 : 60\% \sim$

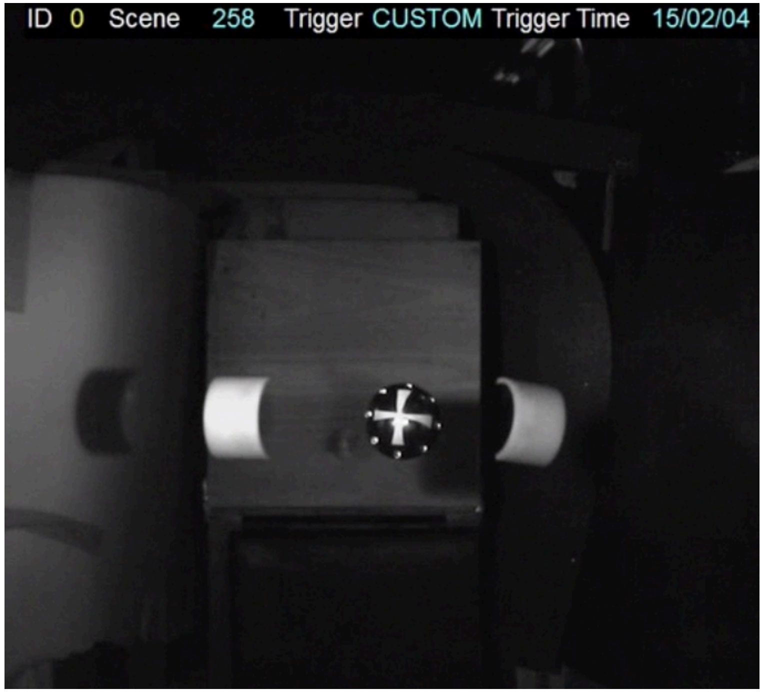




Imapct Test of Crushable Material

Ballistic Range @JAXA Kakuda SC



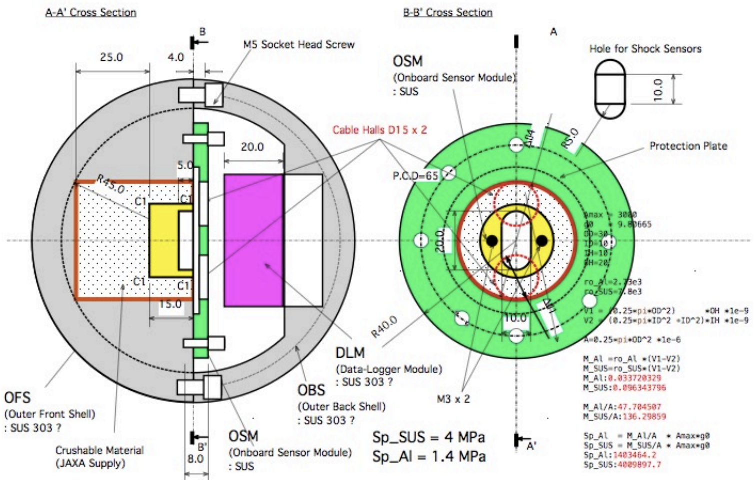


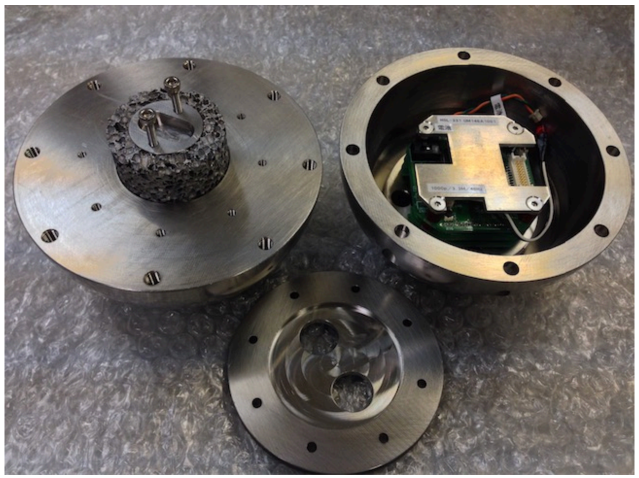
Sensor Module
Weight : 50.5 g
Size : Φ25 x 15

Sensor Module
Weight : 50.5 g
Size : Φ25 x 15

Material
Weight : 12.6 g
Size : Φ40 x 40

Flight Mass : 3,770 kg (w/o Sabot)
incld. Crushable Material 12.6 g

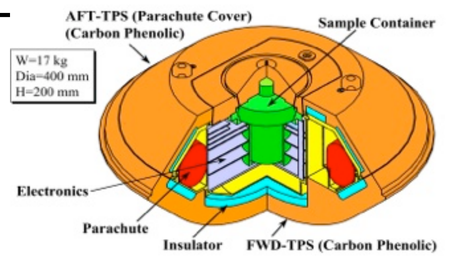


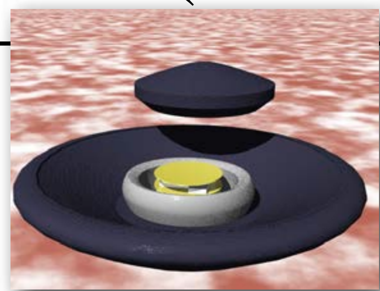


Design Example of High-speed Compact SRC [2/2]

		Hayabusa	High-speed SRC
Capsule	Structure	2250	←
	Heatshield	8915	6700 ※Forward H/S ϕ50 **+Risk Margin 1200 g**
	Inst. Module	2248	
	Pyro. Devises	1070	Crushable Structure(ρ=0.2) 1830
	Parachute	760	
Sampler		1300	←
Capsule Flight Mass		**16.5 kg**	**16.5 kg**
SEP Mecha.		3200	←

Crushable Material
~ t=30 ~ 40 mm



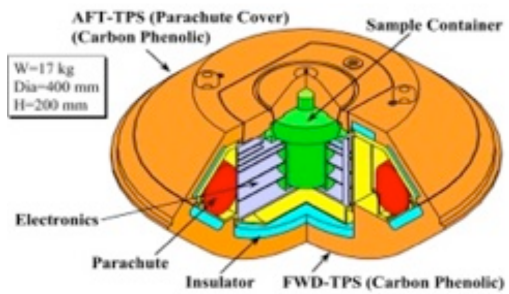


Summary

Compact Capsule
for High-speed Earth Entry
was conceptually designed
and shown with

1) **3-D woven Lightweight Ablator**

2) **Chuteless Landing Design**
with Crushable Material



Hayabusa SRC