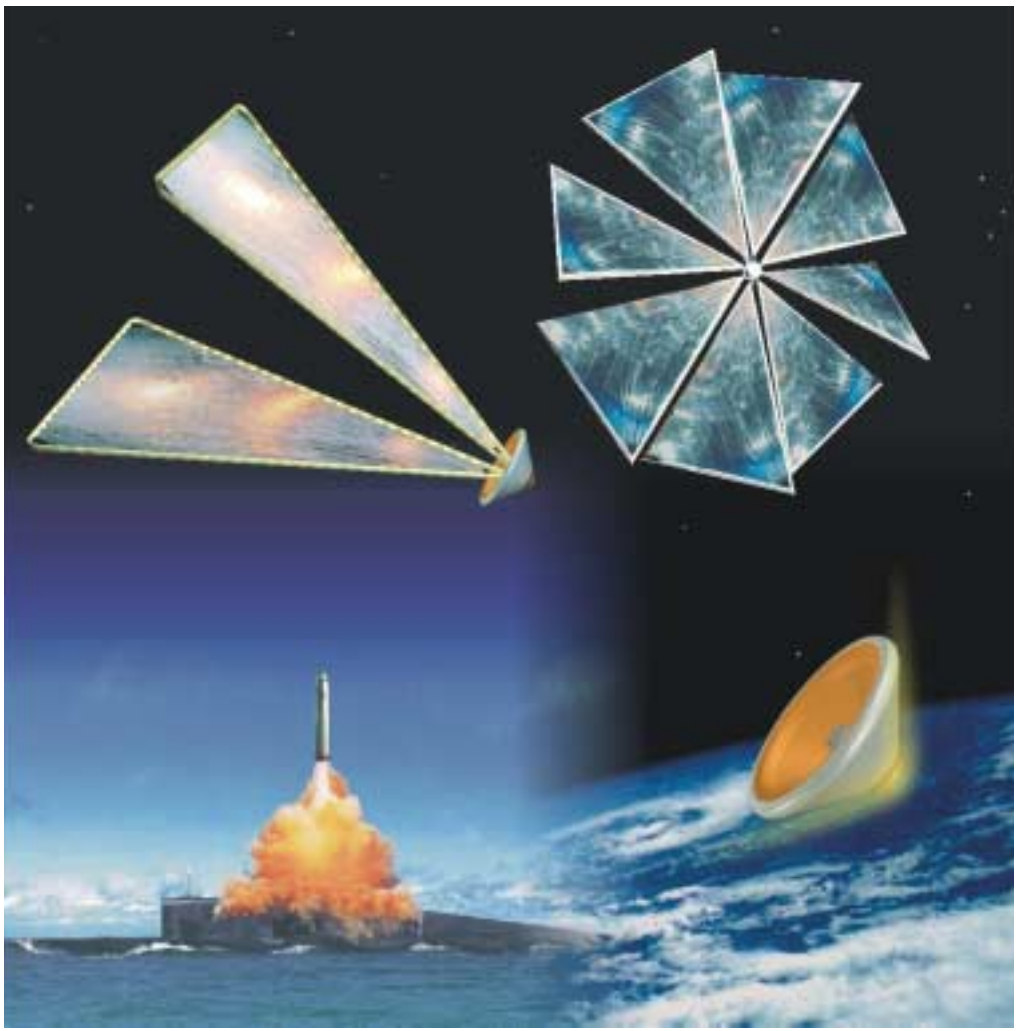
BABAKIN SCIENCE & RESEARCH CENTER
SPACE RESEARCH INSTITUTE RAS

SOLAR SAIL PROJECT



MOSCOW 2001

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

CONCEPT OF SOLAR SAIL PROJECT

1-st phase – technological experiment

1. **Destination –** *solar sail blades deployment verification*
2. **Launch data –** *July 2001*
3. **Launch vehicle –** *insertion by VOLNA LV (converted SLBM SS-N-18) as main payload; launch from submarine from Barents Sea*
4. **Flight configuration –** *flight along the suborbital trajectory; flight results records recovers by IRDT based reentry capsule (landing place – Kamchatka Peninsula)*
5. **Experiment duration –** *~400 s*

2-nd phase – demonstration experiment

1. **Destination –** *solar sail spacecraft operational possibilities demonstration*
2. **Launch data –** *October-November 2001*
3. **Launch vehicle –** *insertion by VOLNA LV (converted SLBM SS-N-18) as main payload; launch from submarine from Barents Sea*
4. **Flight configuration –** *orbital flight; Hα=840 km, Hπ=832 km, i=78°*
5. **Experiment duration –** *about 3 months*

REASONS FOR VOLNA LV CHOICE

1. Payload status is primary.
2. Nothing to change for launch vehicle configuration.
3. Nothing to change for launch preparation campaign.
4. High reliability, based on prototype flight history.
5. Affordable cost.
6. Experience of launches for civilian program.
7. Relatively flexible launch date.

SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

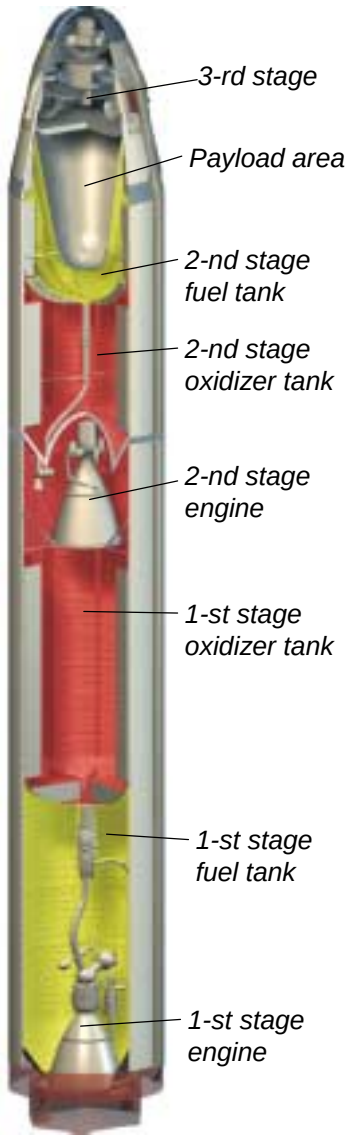
VOLNA LAUNCH VEHICLE

LV VOLNA is being developed by State Rocket Center “Makeyev Design Bureau” on the base of SLBM SS-N-18. VOLNA can be launched from a surfaced or submerged KALMAR (DELTA III) type submarine. Payload of the LV VOLNA is accommodated inside a protected capsule mounted in the warhead section of the SLBM. Basically launch vehicle is intended for suborbital launches.

VOLNA reliability rate, based on SS-N-18 flight history, is 0.95 (total number of launches – 147, among them successful – 140). VOLNA LV was used for insertion german scientific package during microgravity experiment in 1995.

Basic characteristics

Number of stages	*3*
Propellant	*liquid: N_2O_4 + UDMH*
Launch weight	*35.4 t*
Overall dimensions of LV :	
– length	*14.2 m*
– diameter	*1.8 m*
Payload area volume	*1.3 m^3*
Payload mass (into suborbital trajectory)	*up to 720 kg*
Insertion g-loads (longitudinal x lateral):	
- at take-off	*4 x 3*
- at flight	*8 x 2*
Launch point location	*Barents Sea (standard)* *Pacific Ocean (optional)*



SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

1-ST PHASE – TECHNOLOGICAL EXPERIMENT

MISSION PROFILE

Beginning of deployment the solar sail blades. Imaging. T = 573 s

End of deployment the solar sail blades. Imaging. T = 694 s

Lower protective cover separation

VOLNA 3-rd stage overturn. Payload module separation Tsep = 313 s; Hsep = 264 s

Beginning of inflation the recovery capsule braking device

Pressure reducing inside payload compartment

Upper protective cover separation

Solar sail platform separation T = 995 s; H = 150 km

VOLNA 2-nd stage separation. 3-rd stage ignition

Tent = 1037 s H = 100 km V ent = 6372 m/s Θent = -13.2°

Entry into atmosphere

VOLNA 2-nd stage ignition

Aerobraking

VOLNA 1-st stage separation

Inflation of the additional braking device

VOLNA launch from the KALMAR (DELTA III) type submarine

Landing

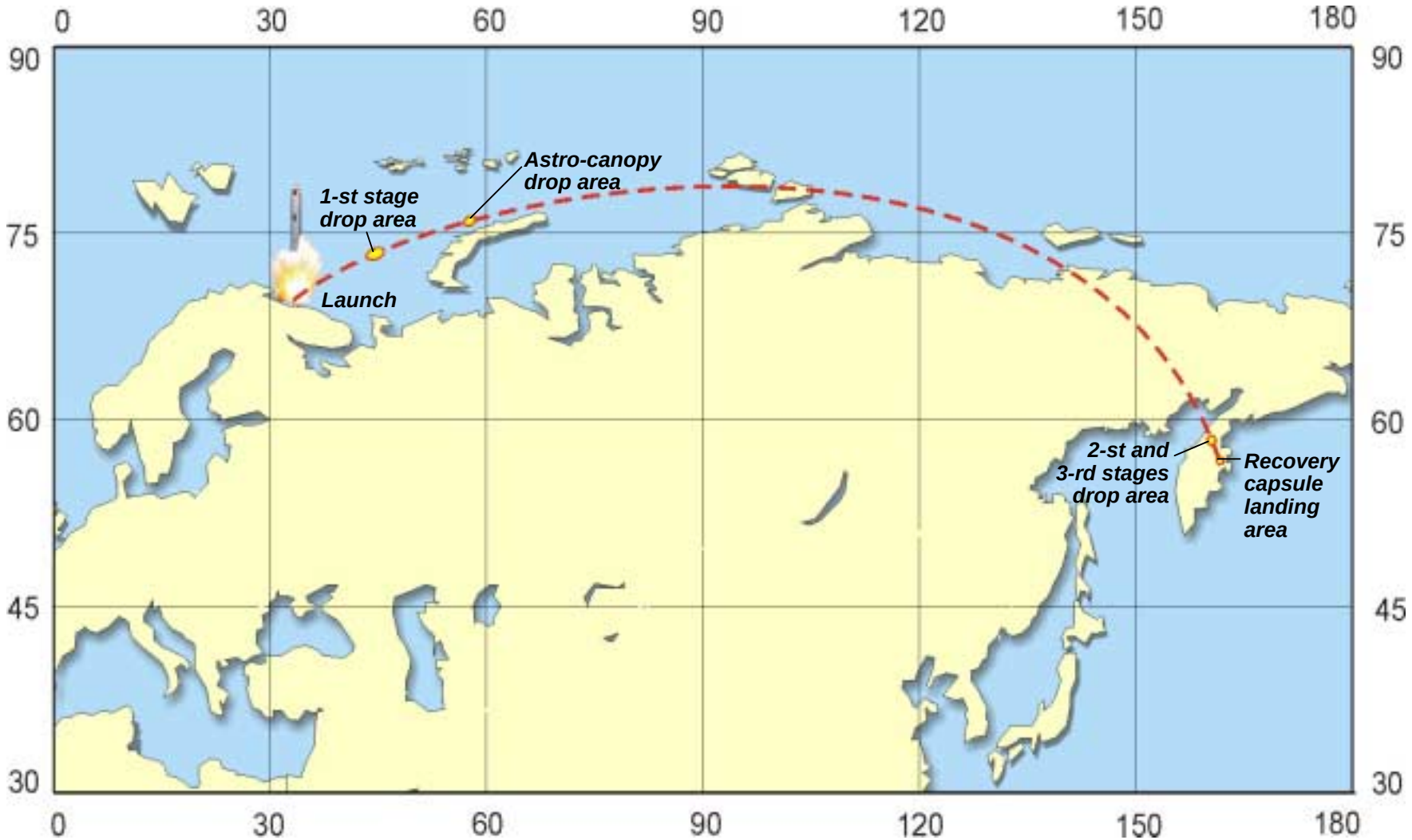
Solar sail deployment altitude…..….	*~400 km*
Solar sail deployment duration……..	*60 s*
Total duration of the solar sail flight..	*422 s*
Apogee altitude……	*411 km*
Apogee time……	*608 s*
Total mission duration……	*1903 s*

SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

1-ST PHASE – TECHNOLOGICAL EXPERIMENT

FLIGHT TRACK

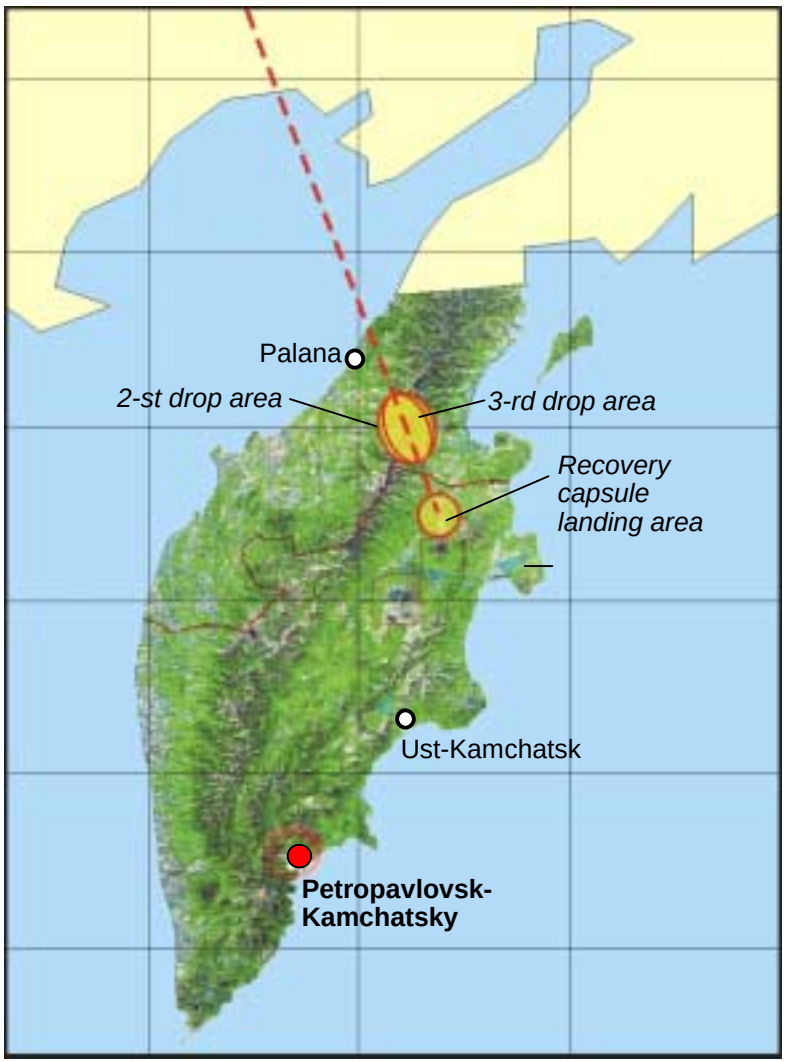


SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

1-ST PHASE – TECHNOLOGICAL EXPERIMENT

RECOVERY CAPSULE LANDING AREA



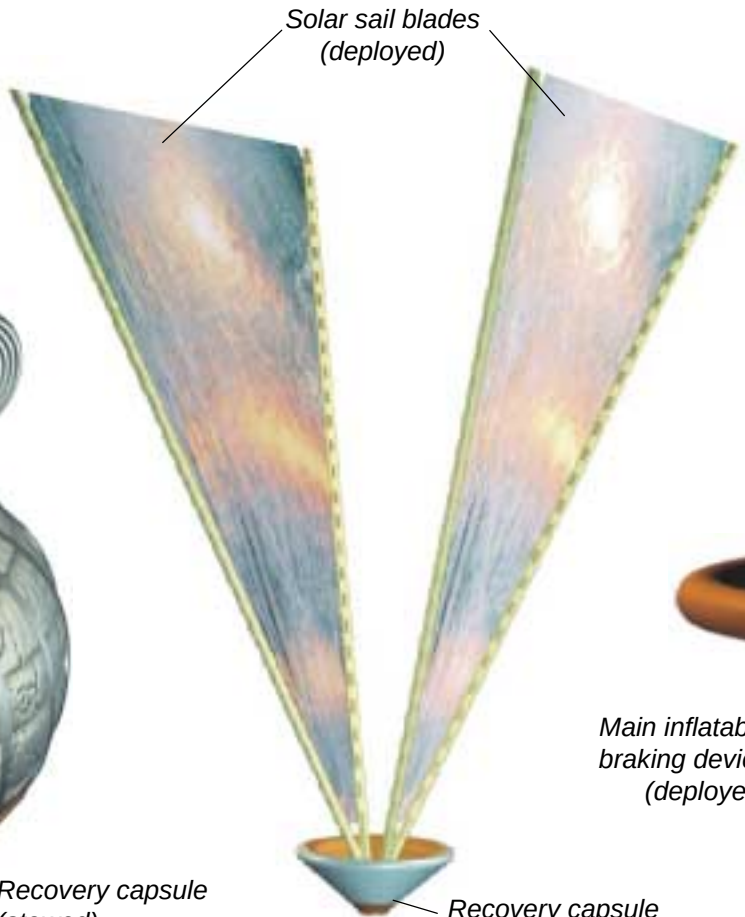
SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

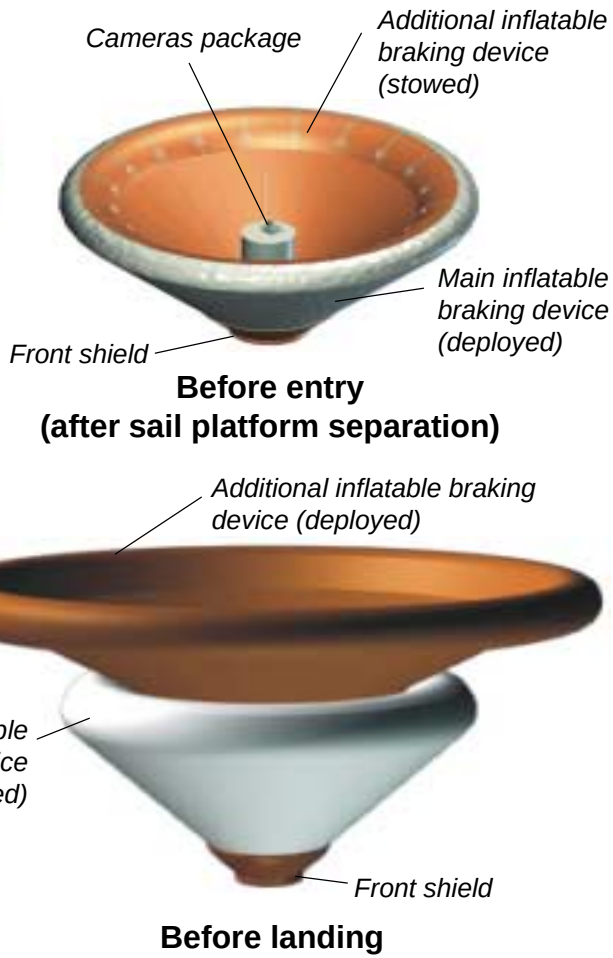
1-ST PHASE – TECHNOLOGICAL EXPERIMENT

SPACECRAFT GENERAL VIEWS

Launch configuration



Flight configuration



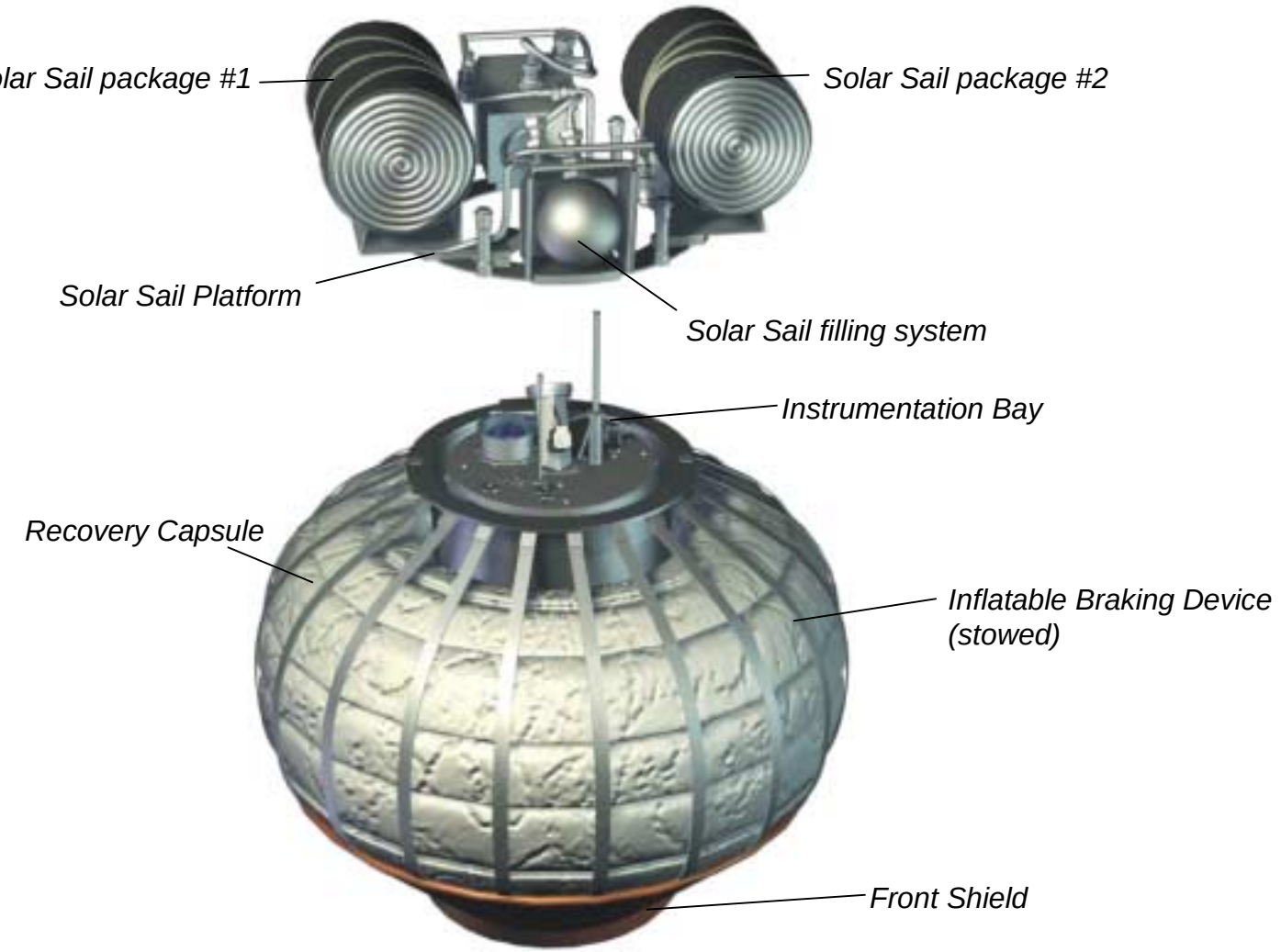
Recovery configurations

SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

1-ST PHASE – TECHNOLOGICAL EXPERIMENT

SPACECRAFT COMPOSITION

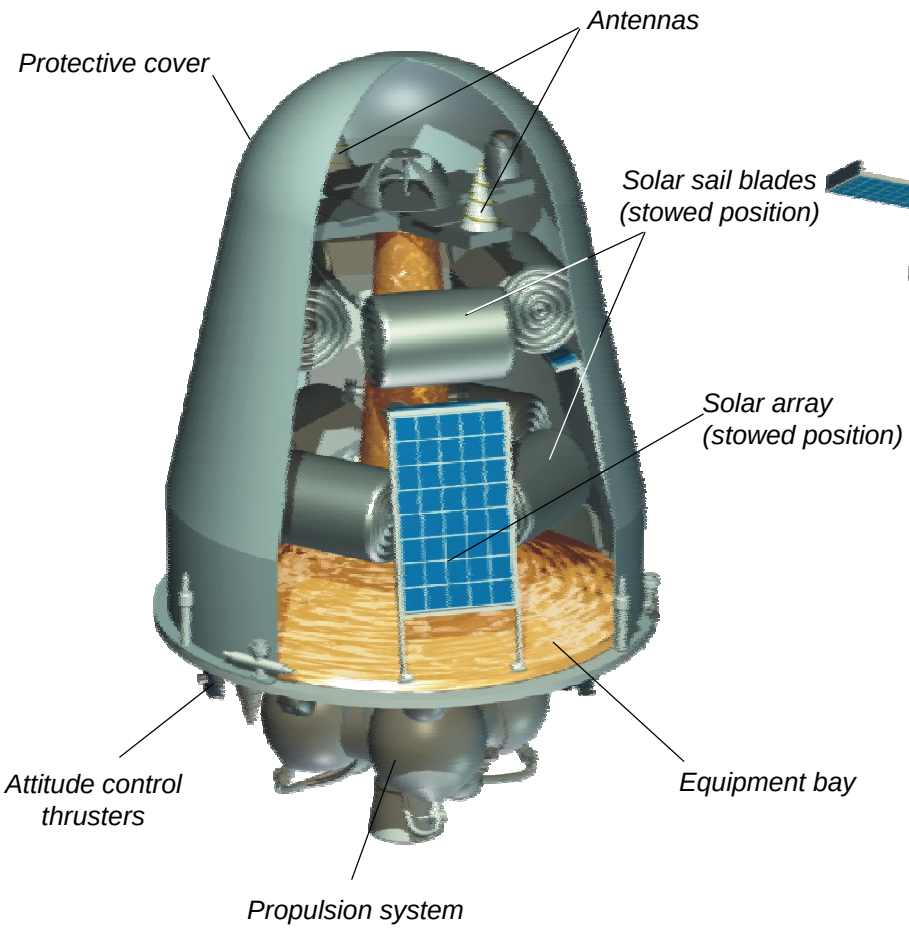


SOLAR SAIL PROJECT

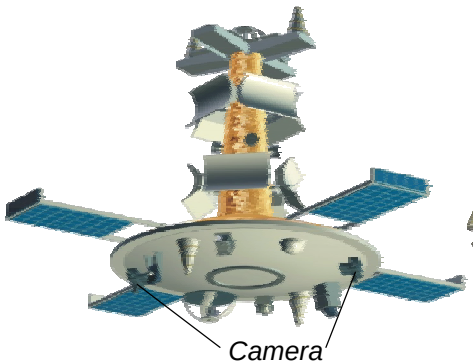
BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

2-ND PHASE – DEMONSTRATION EXPERIMENT

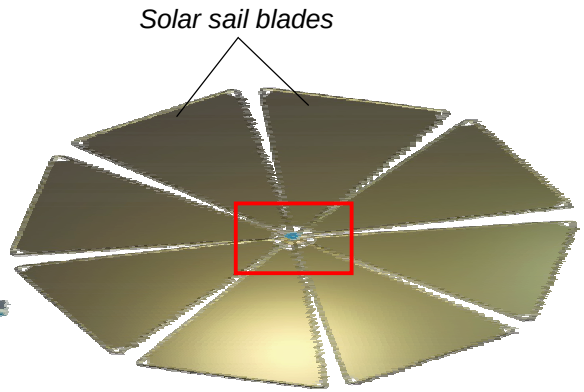
SPACECRAFT GENERAL VIEWS



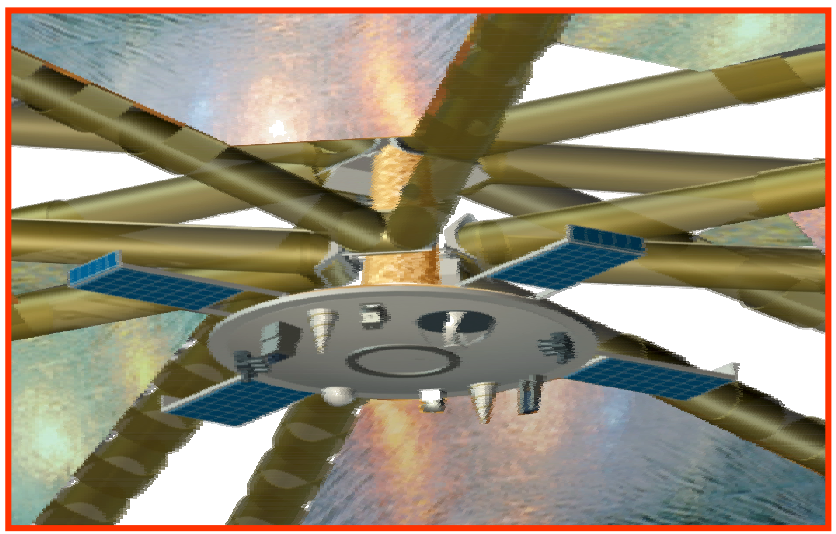
Launch configuration



Orbital platform
(sail is not shown)



Sail deployed configuration



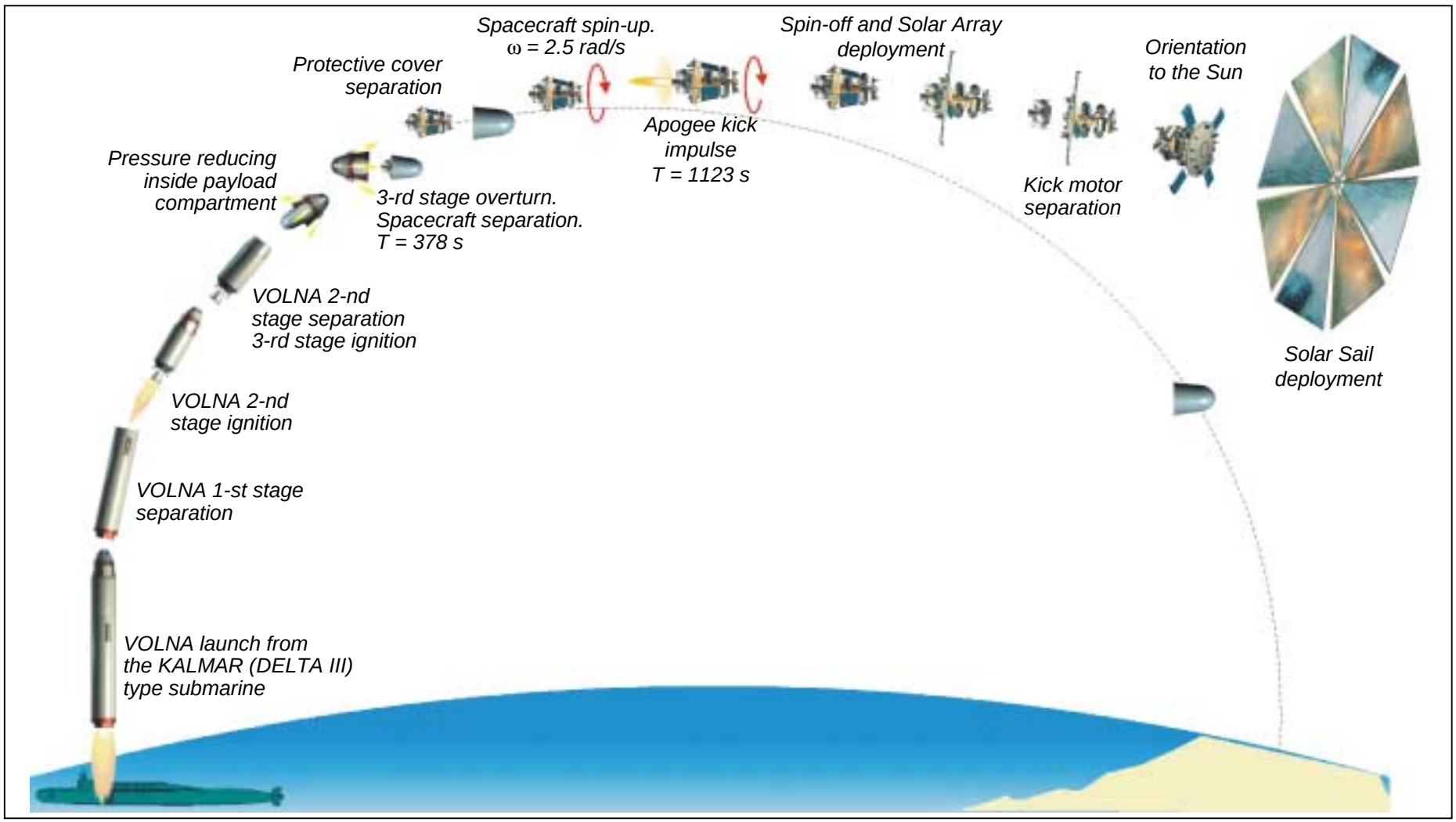
Flight configuration

SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

2-ND PHASE – DEMONSTRATION EXPERIMENT

MISSION PROFILE



2-ND PHASE – DEMONSTRATION EXPERIMENT

SPACECRAFT BASIC FEATURES

Parameter	Value
Mass:	
❑ spacecraft mass, kg	40
❑ Solar Sail mass, kg	9.6
❑ mass of container with the deployment system, kg	32.0
Solar Sail total surface area, m^2	600
Solar sail optical characteristics:	
❑ reflection coefficient	0.86
❑ absorption coefficient	0.14
❑ pass coefficient	0.005
❑ radiation value	0.04
The rate of transmission of telemetry information, kbit/s	1 ÷ 16
Power characteristics:	
❑ solar array square, m^2	0.4
❑ buffer battery capacity, À·h	3.3

SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

SOLAR SAIL TESTS

CHECK OF DEPLOYMENT OF THE SOLAR SAIL BLADE

SOLAR SAIL PROJECT

BABAKIN SCIENCE & RESEARCH CENTER SPACE RESEARCH INSTITUTE RAS

SOLAR SAIL TESTS

DEPLOYMENT TEST WITH MODELING OF ZERO-GRAVITY CONDITIONS