Fall Semester 2004
Part 9

S·P·A·C·E TOURISM II™

Lecture Series given by Dr.-Ing. Robert Alexander Goehlich

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Content

- General
- Guest Speaker: Prof. Yoshiaki Ohkami, Keio University

Note: The following slides were provided courtesy of Prof. Y. Ohkami and Mr. M. Ogawa

- Requests from Audience for Lectures

A New Trend in Manned Space Flight

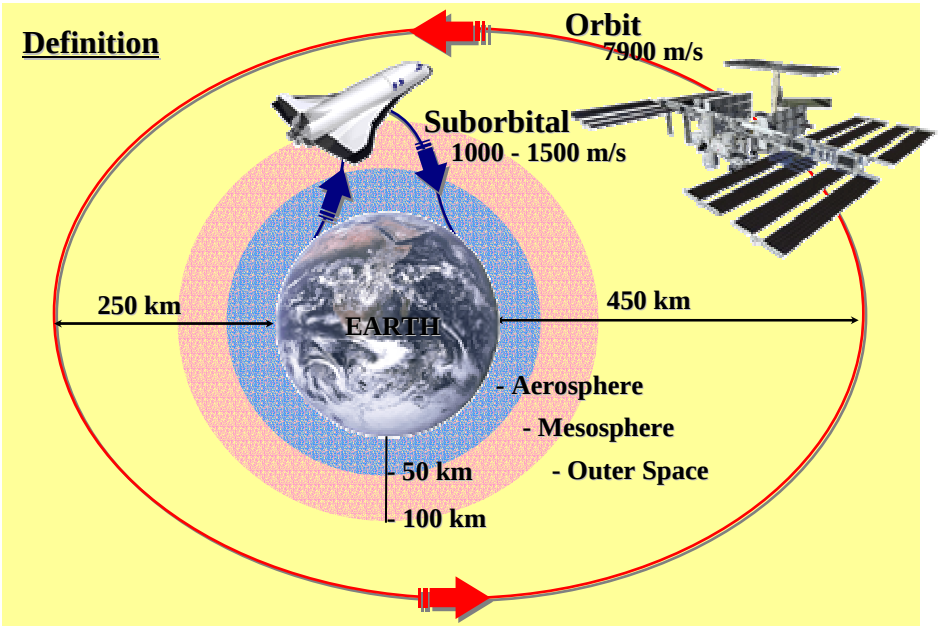
The first manned space flight by a private company was successful to win X-prize in October, 2004

NASA started to investigate the Orbital Space Plane to replace Space Shuttle

A New Trend in Manned Space Flight

Orbital vs. Suborbital

Definition



Mission

- To Design the SoRP satisfying the following constraint
  - Suborbital Rocket Plane

Max Altitude	Over 120 km
Passengers	Over 3 pax and 1 crew
Safety	1 Fault/ 10000 Flight
Price	Under 0.25 M$/pax
Comfort	Under 3 G (Acceleration)

To Achieve the Mission

Requirements	Design Philosophy
▪ Price	▪ Simplicity
▪ Safety	▪ Reusability
▪ Comfort	▪ Reliable Components

Design Sequence

Selection Phase

So Many Concepts

From so many Concepts, 4 concept will be picked in this Phase
Follow Items will be taken account.

- Engine Type
- Take-off and Landing Type
- Stage Number

Investigation Phase

Four Concepts

About 4 Concepts, Vehicle Concept Verification will be done
By Shape and Trajectory Simultaneous Optimization Method.
And then Best Concept will be decided.

Concept Design Phase

One Concept

About the Best Concept, More detailed Design will be done
By Conventional Design Method using CAD

Concepts

SoRP Concept will be generated by selecting elements of follows.

Stage Number
1 Stage, 2 Stage, 3 Stage, 4 Stage

Take-off Type
Vertical or Horizontal

SoRP Concept

Landing Type
Vertical or Horizontal

Propulsion System
Rocket, ABE*

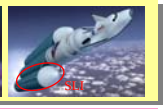
Reusability
Fully or Partially

* ABE: Air Breathing Engine

Stage : The System that contributes Acceleration or Ascent to achieve Space

Rocket (RKT)
Rocket Propulsion System
for Ascent and Acceleration

Solid Rocket Booster (SRB)
Rocket Propulsion System for only Lift-off
Cut off from the Orbiter just after Lift-off

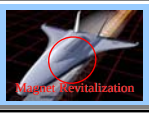


Flyback Booster (FBB)
Returnable Rocket Propulsion System
Not using Aerodynamic Force in Ascent

Airplane (PLN)
Airplane System for Ascent and Acceleration
Using Aerodynamic Force in Ascent

Balloon (BLN)
Balloon System just for Ascent or Descent

Sled (SLD)
Ground Take-off Support System
(e.g: MagRev, Train, Ship, Ekranoplan)



System Configuration

System				Stage 1						Stage 2			Stage 3			Stage 4			
Take-off	Landing	Reusability	Stage	PLN	SLD	RKT	FBB	SRB	BLN	PLN	RKT	FBB	PLN	RKT	FBB	PLN	RKT	FBB	Concept
H	H	F	S	◎															53 (17)
H	H	F	M	○						◎			○						50 (12)
				○						○			◎						6
					○					◎									4
					○					○			◎			○			1
					○					○						◎			1
H	H	P	M	○											◎				2
				○						○				○				◎	2
H	V	F	M	○						◎									1
					○					◎									1
V	H	F	S				◎												14 (2)
V	H	F	M				○					◎							35
							○					○			◎				5
						○						◎							8
								○				◎							7
									○	◎									1 (1)
						○									◎				14 (1)
V	H	P	M			○									○				1
							○					◎			○				2
								○			○				○				4
						○					○			○				◎	7
								○			○			○				○	4
V	V	F	S			◎													51 (15)
V	V	F	M				○				◎								1
									○		◎								2 (2)
V	V	P	M			○					○			◎					4 (2)

Too Complex

Not Safe

Too Complex

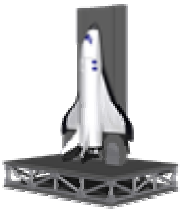
Not Safe

H: Horizontal V: Vertical

F: Fully Reusable P: Partially Reusable

S: Single Stage M: Multi Stage

Concept A



Aspect

- Vertical Take-off / Horizontal Landing
- Usage of Conventional Runway for Landing
- Single System

Flight Profile

Vertical Ascent Phase

Ascending until Lift increases over Own Weight
At 90 deg Path Angle with 0 deg Attack Angle
From 0 m/s Initial Velocity

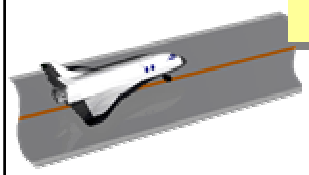
Powered Flight Phase

Ascending by Rocket Power
From the States of the End of Vertical Ascent Phase
Optimized by DGV Method

Coasting Phase

Ascending without Rocket Power
From the Altitude of 50 – 100 km every 5 km
With 0 deg Attack Angle

Concept B



Aspect

- Horizontal Take-off / Horizontal Landing
- Usage of Conventional Runway for Take-off & Landing
- Single System

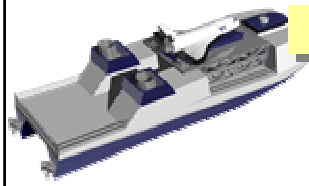
Flight Profile

Running Phase
Running on the Conventional Runway
With own Running Gear
Until the Lift increases over own Weight

Powered Flight Phase
Ascending by Rocket Power
From the States of the End of Running Phase
Optimized by DGV Method

Coasting Phase
Ascending without Rocket Power
From the Altitude of 50 – 100 km every 5 km
With 0 deg Attack Angle

Concept C



Aspect

- Horizontal Take-off from the Extant Ship “Hishoh”
- Horizontal Landing on the Conventional Runway
- Two Stage System

Flight Profile

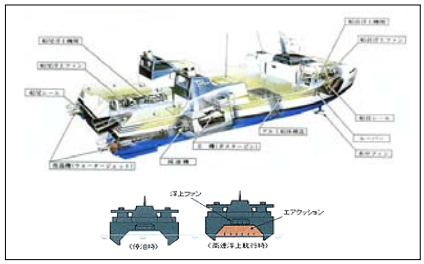
Cruising Phase
Cruising on the Sea with the Ship for Acceleration
Until 55.8 m/s (105 knot) that’s double of Cruise Speed
Unoptimized in the Optimization Sequence

Powered Flight Phase
Ascending by Rocket Power at the Velocity of 55.8 m/s
and the Attack Angle of 20 deg
Optimized by DGV Method

Coasting Phase
Ascending without Rocket Power
From the Altitude of 50 – 100 km every 5 km
With 0 deg Attack Angle

Techno Super Liner - HISYOH -

Velocity	52.45 knot (27.91 m/s)
Sale	23,000 yen × 100,000 pax/year
Route	Tokyo Bay – Ogasawa Islands
Cruise Time	23 hour (One Way)
Payload	1,000 kg
Size (L×W×H)	70 m × 18.6 m × 9.5 m



Reference: http://www.bekkoame.ne.jp/~syu-kun/TSL2.html

Concept D

Aspect

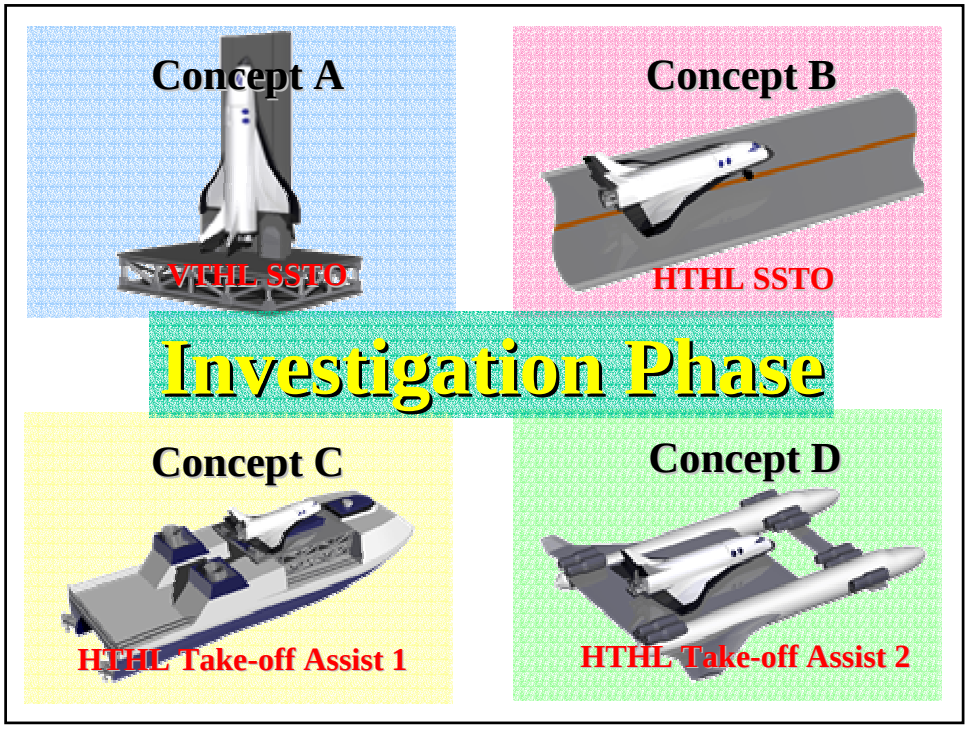
- Horizontal Take-off from Ekranoplan
- Horizontal Landing on the Conventional Runway
- Two Stage System

Flight Profile

Cruising Phase
Cruising on the Sea with Ekranoplan for Acceleration
Until 170 m/s that's half of Sonic Velocity
Unoptimized in the Optimization Sequence

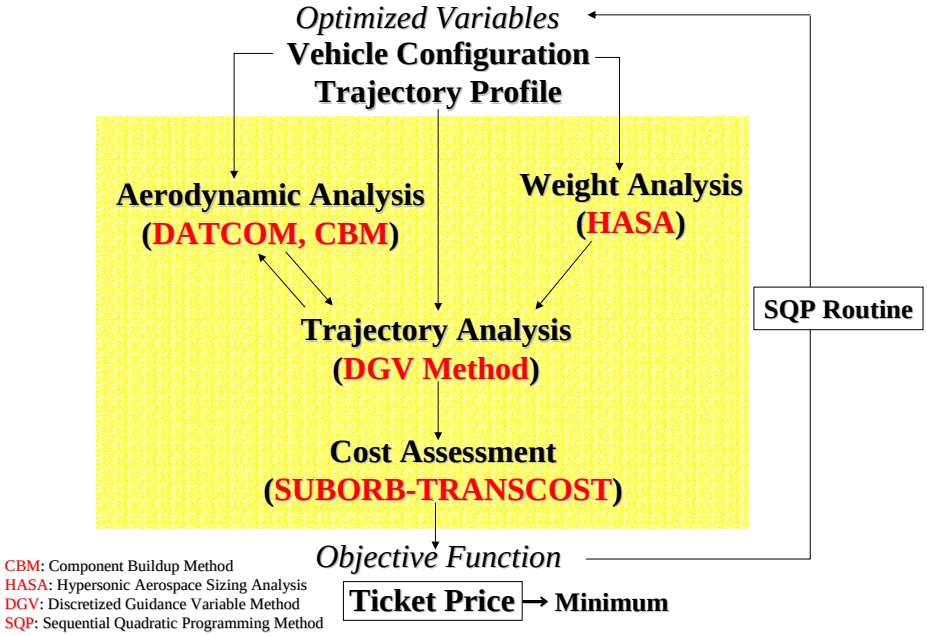
Powered Flight Phase
Ascending by Rocket Power at the Velocity of 170 m/s
and the Attack Angle of 20 deg
Optimized by DGV Method

Coasting Phase
Ascending without Rocket Power
From the Altitude of 50 – 100 km every 5 km
With 0 deg Attack Angle


Concept A
VTHL SSTO
Concept B
HTHL SSTO
Investigation Phase
Concept C
HTHL Take-off Assist 1
Concept D
HTHL Take-off Assist 2

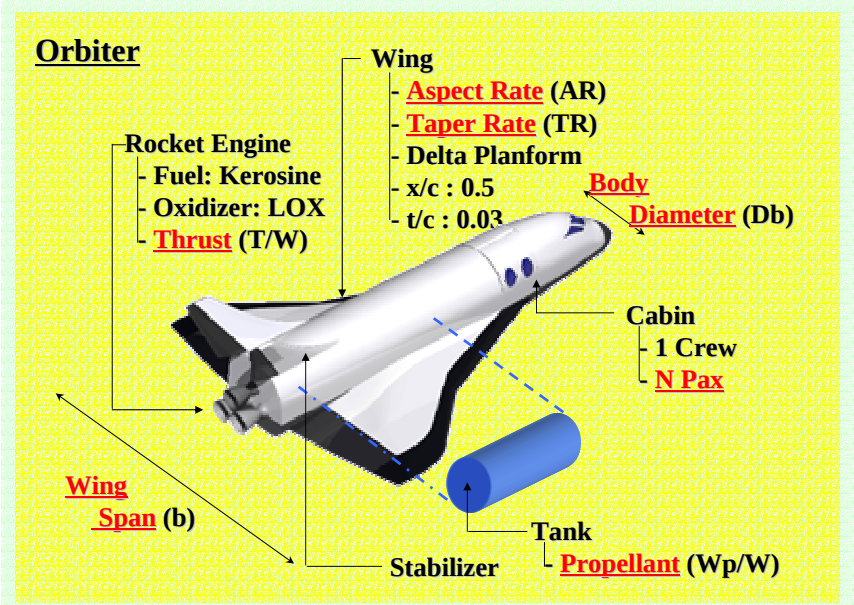

Take-off
Powered Flight
Coasting
On Orbit
Concept A
Concept B
Concept C
Concept D
By RP-1/LOX Rocket Engine
Dynamic Pressure < 40 kPa
Attack Angle < 25 deg
Acceleration < 3 G
Attitude Angle < 90 deg
From 50 - 100 km
Unpowered
With 0 deg Attack Angle
Over 120 km

Design Method

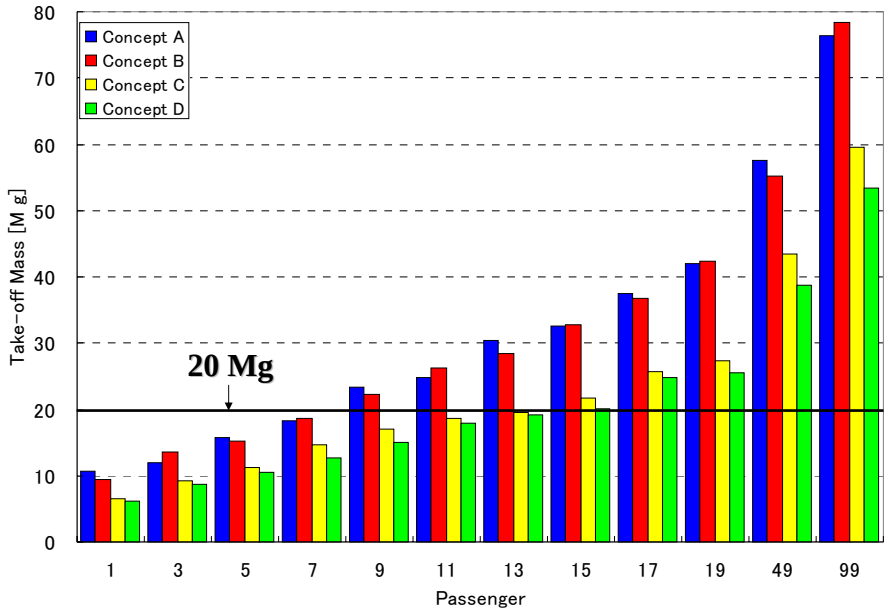


CBM: Component Buildup Method
HASA: Hypersonic Aerospace Sizing Analysis
DGV: Discretized Guidance Variable Method
SQP: Sequential Quadratic Programming Method

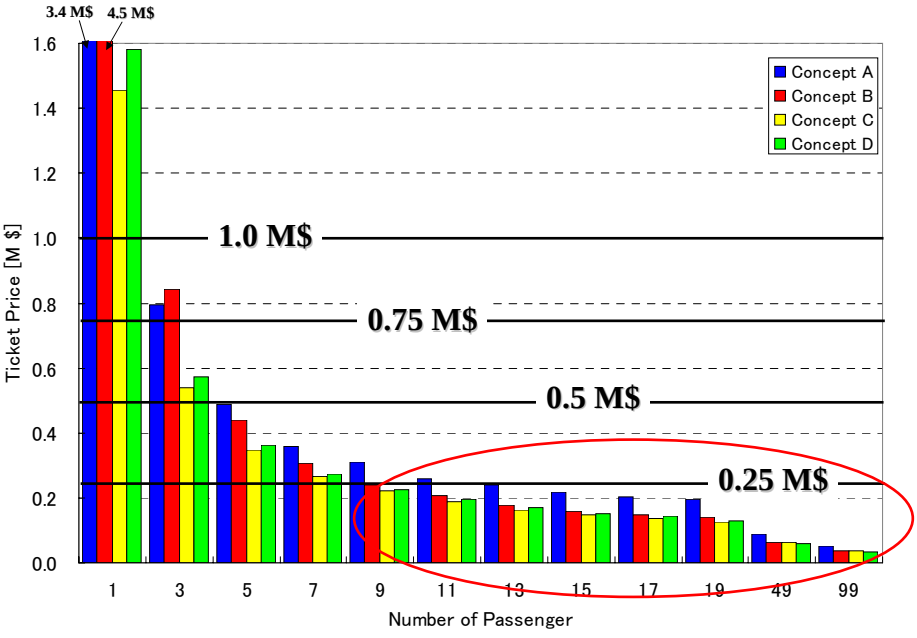
Vehicle Parameter



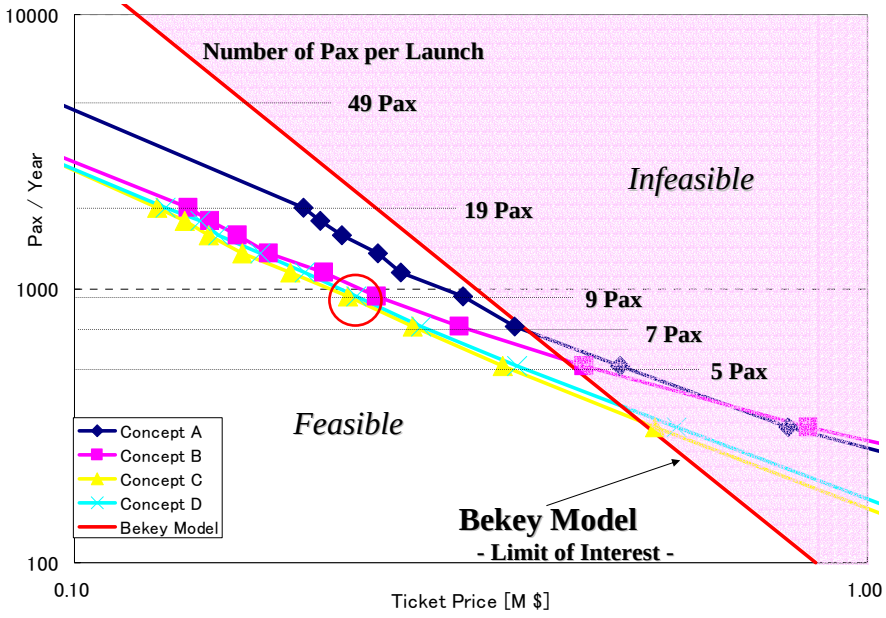
Result – Take-off Mass



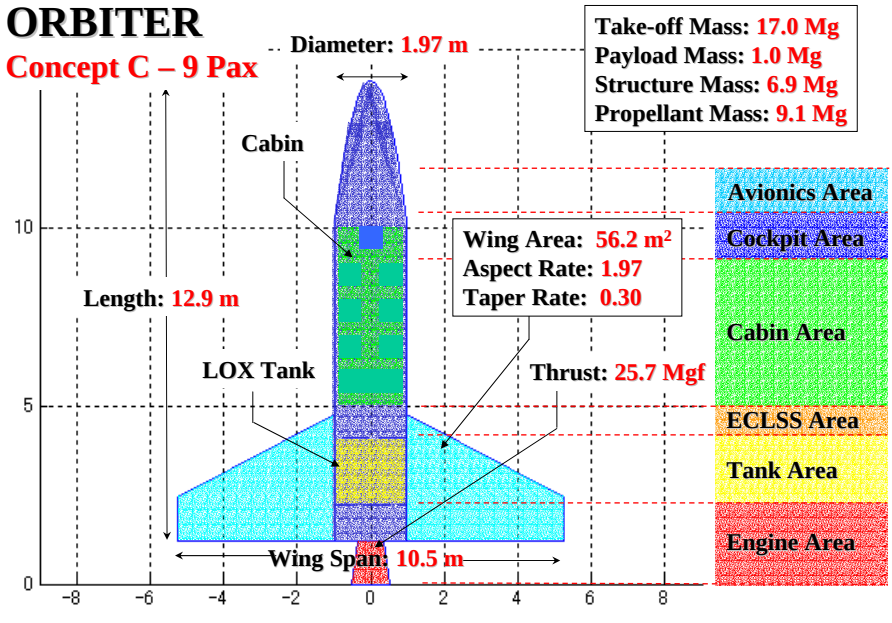
Result – Ticket Price (SUBORB-TRANSCOST Model)



Result – Economical Feasibility

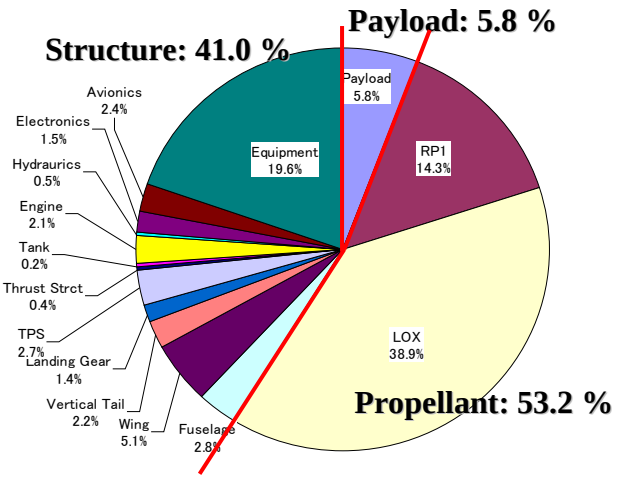


Optimum Concept - Shape



Optimum Concept - Mass

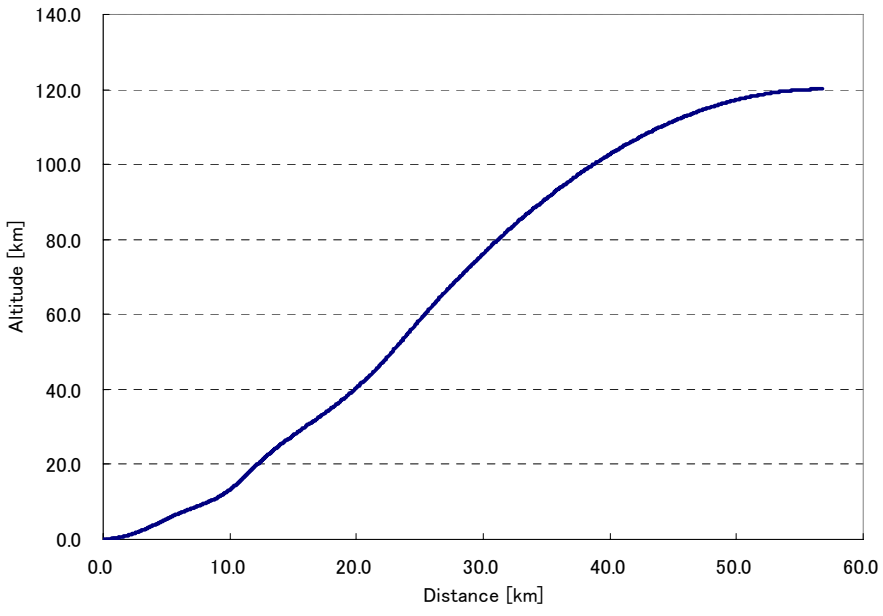
Take-off Mass: 17.0 Mg
Payload Mass: 1.0 Mg
Structure Mass: 6.9 Mg
Propellant Mass: 9.1 Mg



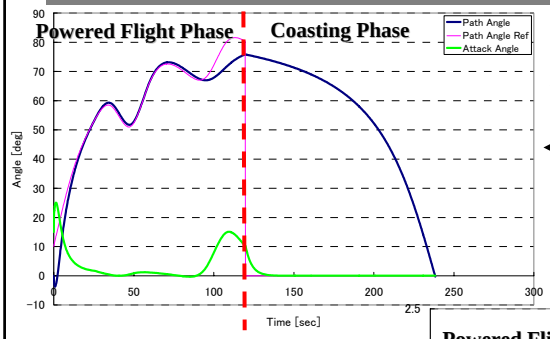
Detailed Information

Gross	17044 kg
Payload	1000 kg
Propellant	9114 kg
RP1	2450 kg
LOX	6664 kg
Structure	6930 kg
Fuselage	487 kg
Wing	878 kg
Vertical Tail	372 kg
Landing Gear	244 kg
TPS	469 kg
Thrust Strct	64 kg
Tank	34 kg
Engine	366 kg
Hydraurics	89 kg
Electronics	262 kg
Avionics	405 kg
Equipment	3361 kg

Optimum Concept - Trajectory



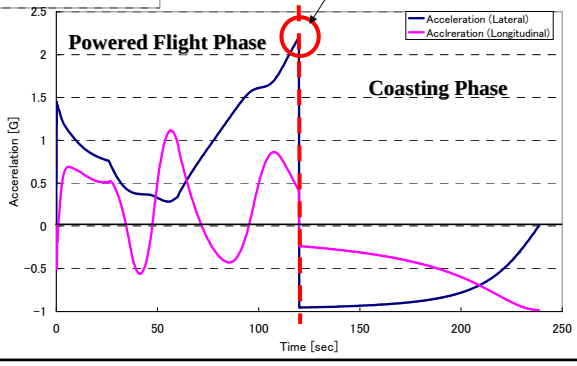
Trajectory Selected Concept - Trajectory



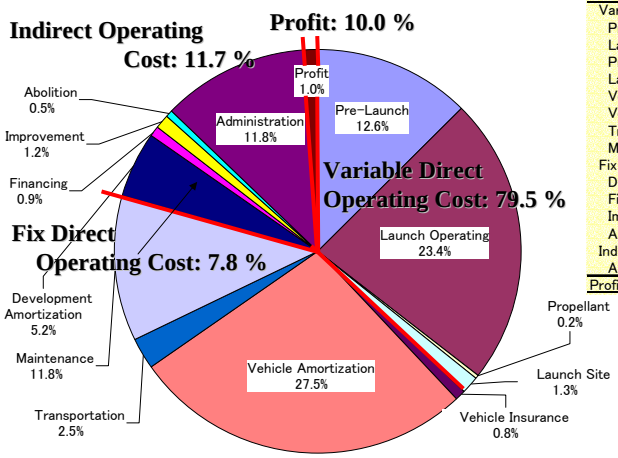
Path Angle & Attack Angle

Max Acceleration: 2.2 G

Acceleration

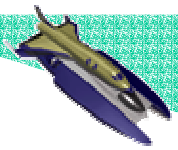


Optimum Concept - Cost



Detailed Information

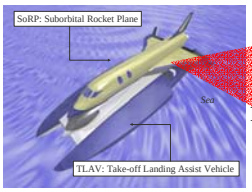
Development	149.135	M$
Winged Vehicle	48.298	M$
Rocket Engine	100.838	M$
Production	44.956	M$
Winged Vehicle	42.628	M$
Rocket Engine	2.328	M$
Operation	1.832	M$/Launch
Variable Direct Operating Cos	1.471	M$/Launch
Pre-Launch	0.231	M$/Launch
Launch Operating	0.429	M$/Launch
Propellant	0.004	M$/Launch
Launch Site	0.024	M$/Launch
Vehicle Insurance	0.015	M$/Launch
Vehicle Amortization	0.504	M$/Launch
Transportation	0.046	M$/Launch
Maintenance	0.219	M$/Launch
Fix Direct Operating Cost	0.145	M$/Launch
Development Amortization	0.096	M$/Launch
Financing	0.017	M$/Launch
Improvement	0.023	M$/Launch
Abolition	0.009	M$/Launch
Indirect Operating Cost	0.216	M$/Launch
Administration	0.216	M$/Launch
Profit	0.191	M$/Launch



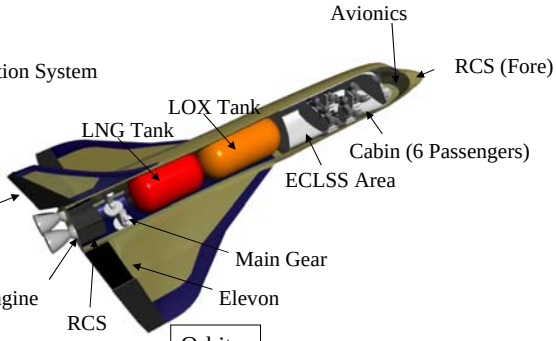
Concept Design
Preliminary Design
Detail Design

System

HTHL Suborbital Space Transportation System



Operation



Orbiter

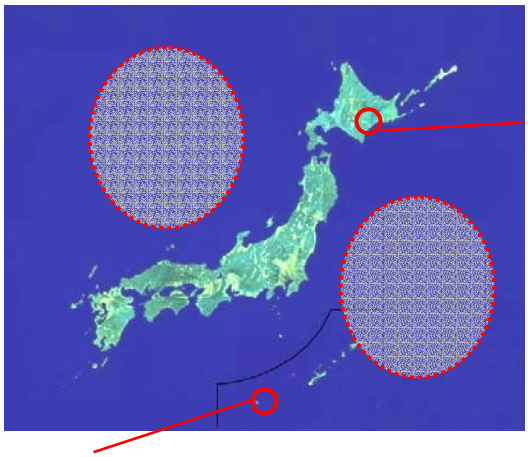
Proof of Concept Experiment

Winged Vehicle Flight Tests in Overseas Areas

ALFLEX in Australia in July 1996
SST in Australia in July 2002
HST in Christmas Ils. in Nov. 2002
HST in Sweden in 2003

Test Range like Mojave Desert Exists in Japan?

No, even Hokkaido or Okinawa is not sparse enough.



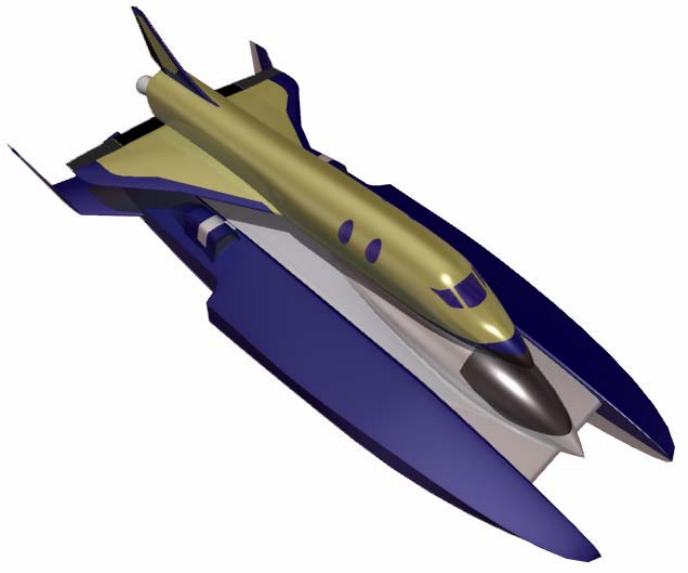
Taiki Town

Shimoji Island

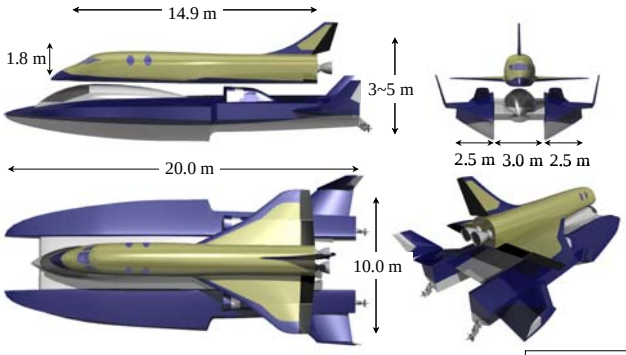
Solution – Use of open sea!

Proof-Of-Concept Approach

SoRP Concept



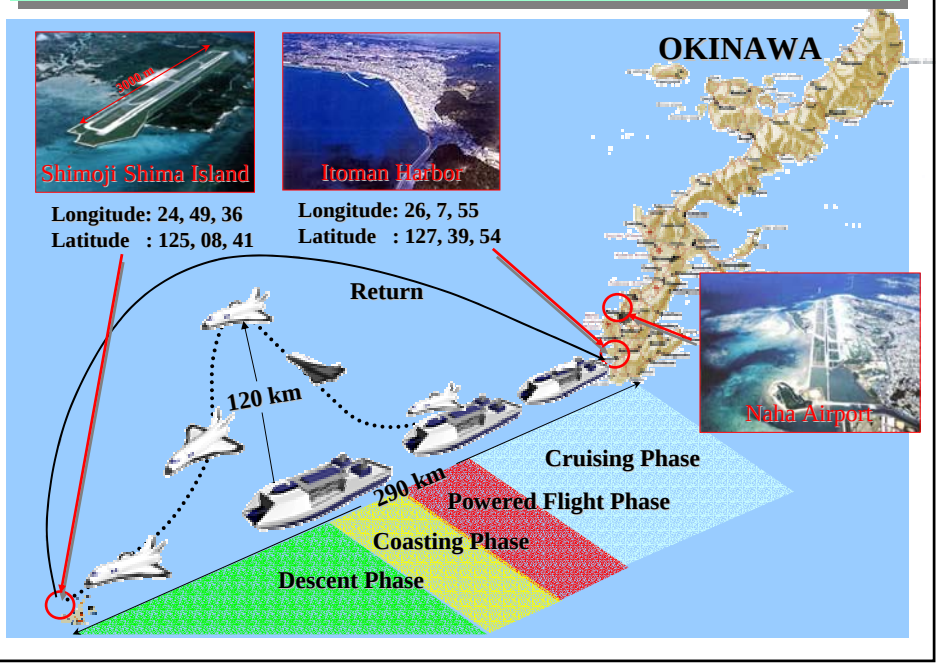
Majpor Specifications



High Speed Boat	
Length:	20.0 m
Wing Span:	10.0 m
Height:	3~5 m
Power:	2×1075 HP
Max Speed:	200~250 km/h

SoRP	
Take-off Mass:	13.96 Mg
Propellant Mass:	7.70 Mg
Length:	14.9 m
Wing Span:	8.27 m
Body Diameter:	1.8 m
Wing Area:	39.8 m^2
Thrust (vac):	2×97 kN
Isp (vac):	345 sec

Operations and Tour Plan



Operations Scenario

1st Day/ Flight to Naha Airport in Okinawa
2nd Day/ Preparation for flight with health check-up
3rd Day/ Boarding to mother ship to leave the harbor
Boarding to "SoRP" to move to the "Site"
Confirmation of Take-Off readiness
Start of engines and full acceleration
Take-off and climbing to "Space"
Reach "Space" with altitude of 120 km
Return to the Earth and landing
Briefing and receipt of space tour certification
"Astronaut Wing" awarded
4th day/ Return flight from Naha Airport

A few Days for maintenance, repair, refueling etc.

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