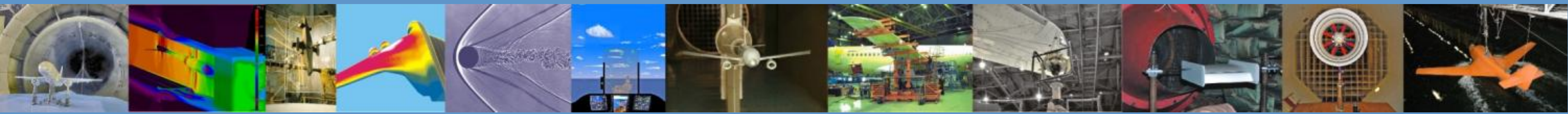


Configuration of aerospace system concept on alternative fuels

Young researcher in TsAGI
S. Mikhalev

ANNOTATION

- **Object** – intercontinental aerospace system

- **Aim of the work** – design new generation aerospace system configuration, calculate flight path and estimate the impact of different fuels on the main technical characteristics of space-rocket system (payload mass, overall dimensions of stages, fuel tanks volume and etc.)

- **References**

1. *L.M. Shkadov, V.Ye. Denisov, V.V. Lazarev, V.P. Plokhikh, V.I. Buzuluk, S.V. Volodin, K.A. Chervonenko and V.V. Skipenko*. The comparative analysis of various aerospace system concepts. – Acta Astranautica Vol. 35, No. 1, pp. 47-54, 1995, том LXVIII, № 4-6.
2. *V.I. Buzuluk Optimizatsiya traektorii dvizheniya aerokosmicheskikh letatel'nykh apparatov* (Aerospace aircraft mechanical trajectory optimization), Moscow, TsAGI, 2008, 476 p.
3. *S. Mikhalev Aerokosmicheskaya sistema dl'a mezhkontinental'nikh perel'otov* (Intercontinental aerospace system), *Trudy MAI* (Moscow Aviation Institute Papers), http://www.mai.ru/science/trudy, 81th issue, may 2015.

- **Executed** in TsAGI by Dr. V.Buzuluk, R.Vasilyev, S.Mikhalev and etc., 2014-2015

Overview

- General Description of Aerospace system concept
- Development of Aerospace system
- Subsystem definitions
- Aerodynamic and Flight paths calculations
- Economic efficiency

Background

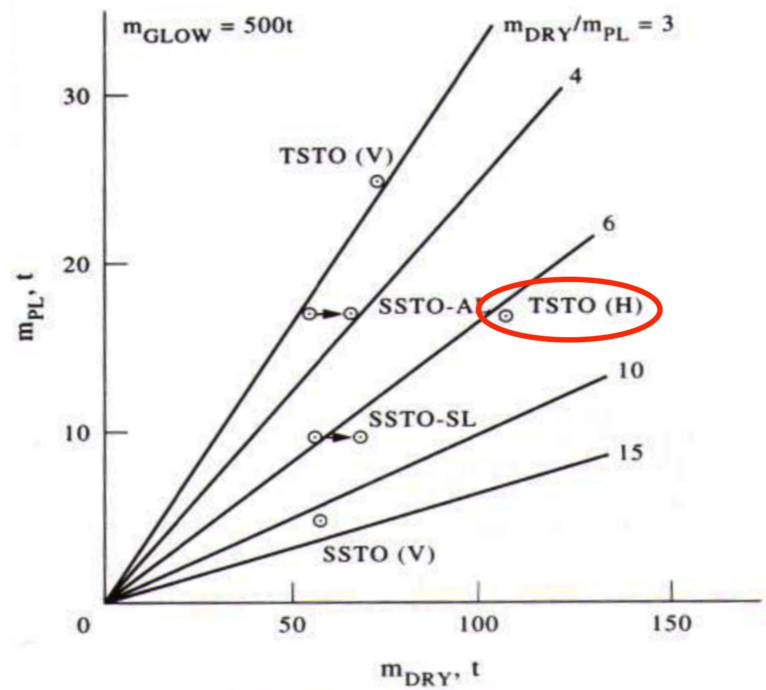
Payload mass-dry mass correlation for the STS (space transportation system) concepts is presented herein. There are given six major alternatives rocket powered STS concepts:

Single-stage-to-orbit transportation systems (SSTO) capable of:

- HTO using an undercarriage [SSTO(H)];
- Sled-assisted takeoff [SSTO-SL];
- Air-launch [SSTO-AL];
- Ground VTO [SSTO(V)];

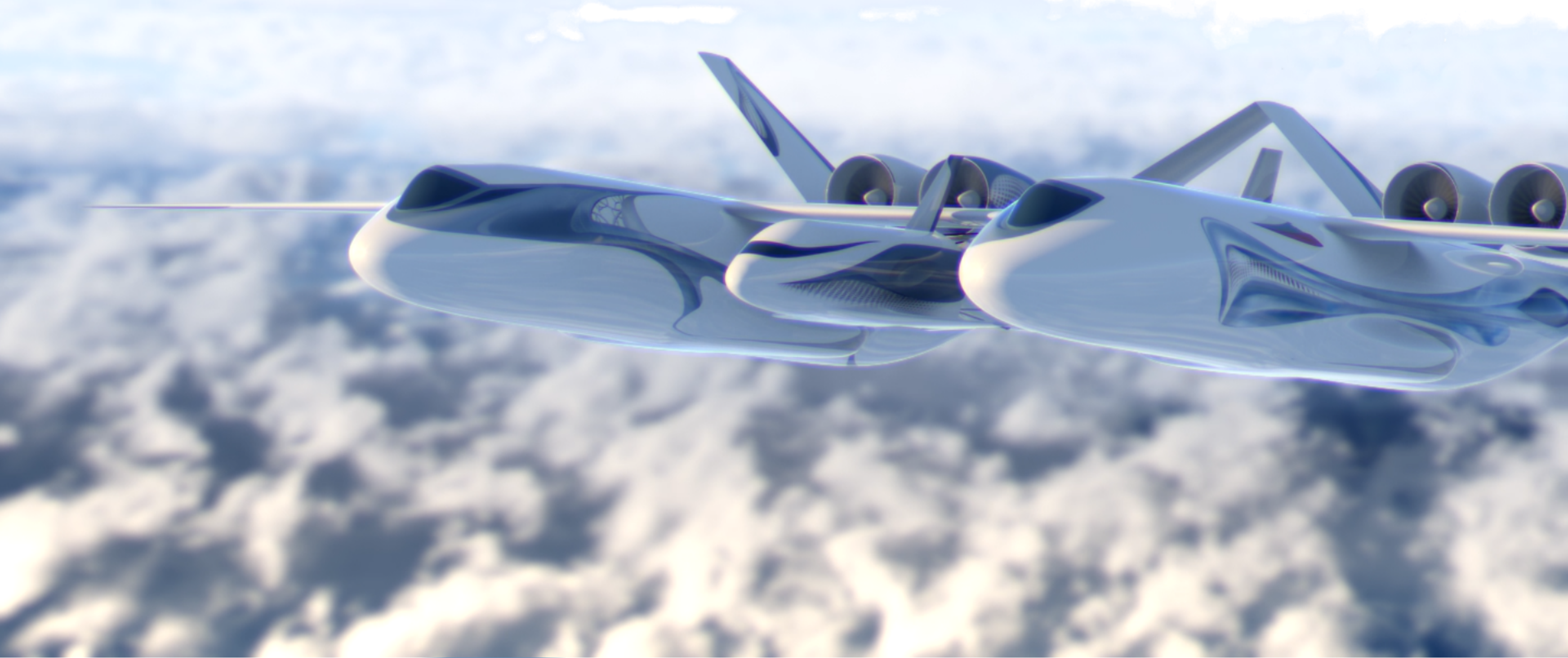
Two-stage-to-orbit transportation systems (TSTO) capable of:

- HTO using an undercarriage [TSTO(H)];
- Ground VTO [TSTO(V)].



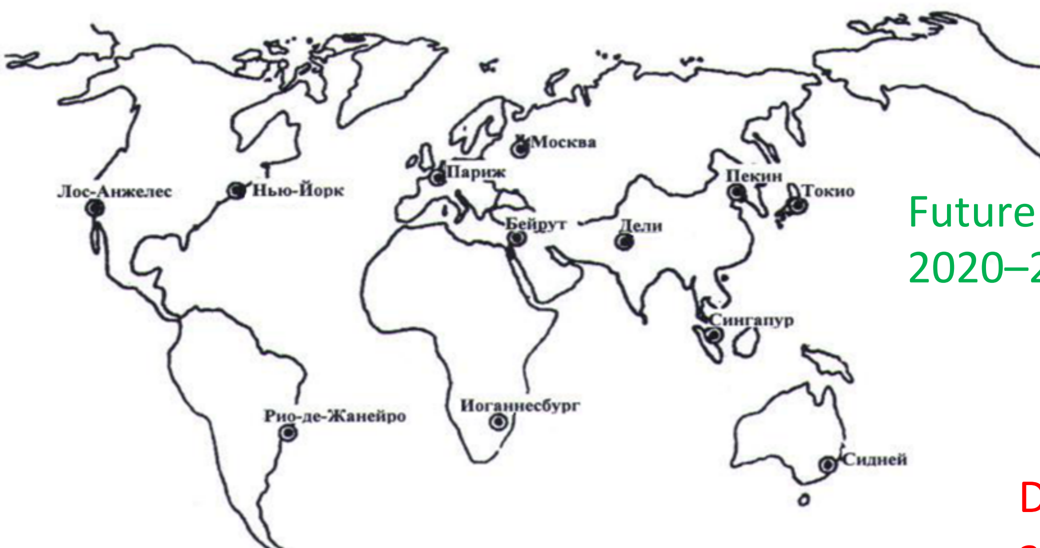
General Description of Aerospace system concept

- Low-cost space transportation to orbit or
- Ultra-long distance travel (flight range up to 15 000 km.)
- Minimal environmental effects of emissions



Intercontinental travel

Today

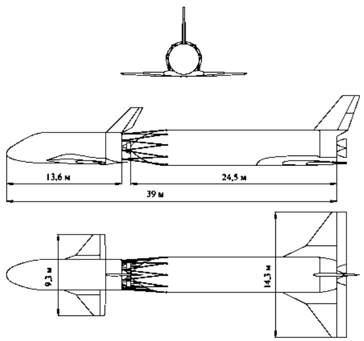


Future
2020–2025

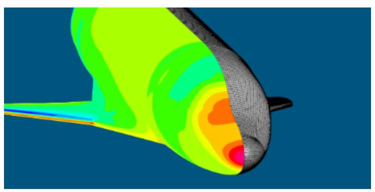
Hypersonic airplane (scramjet)

Distant future
after 2035

Development



Design



Aerodynamic

Visual Studio
FORTRAN

Multicriterion calculation

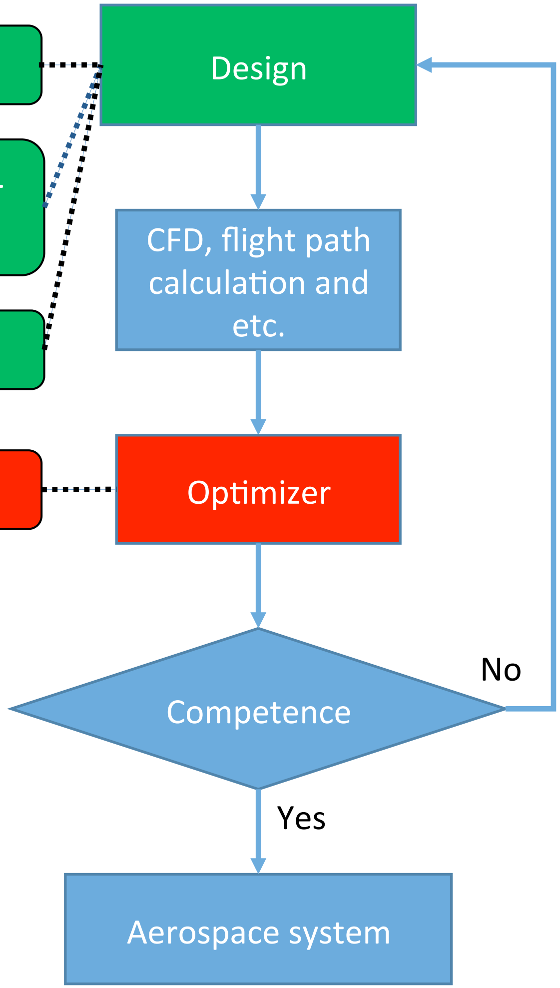
Result

Design aerospace system configuration

Aerospace system: TSTO rocket system (RS) + subsonic carrier (SC)

Heavy carrier M-60VTM as base for SC

Parameters optimization

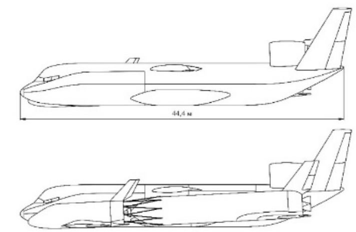


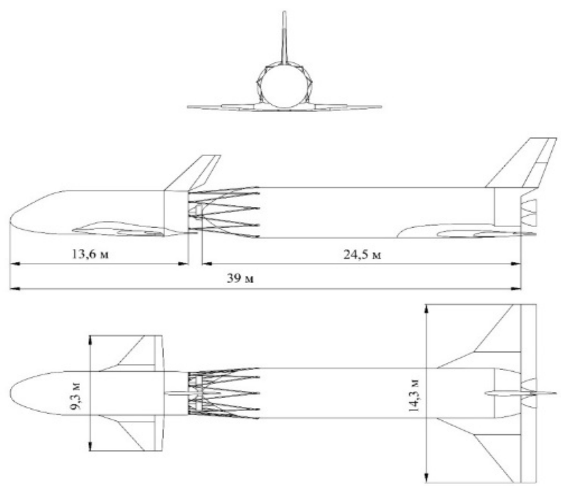
During the plane design fuel options for next-generation hypersonic plane-booster and hypersonic plane are crucial. Three fuels: **kerosene**, liquefied **methane** and liquefied **hydrogen** were under consideration.

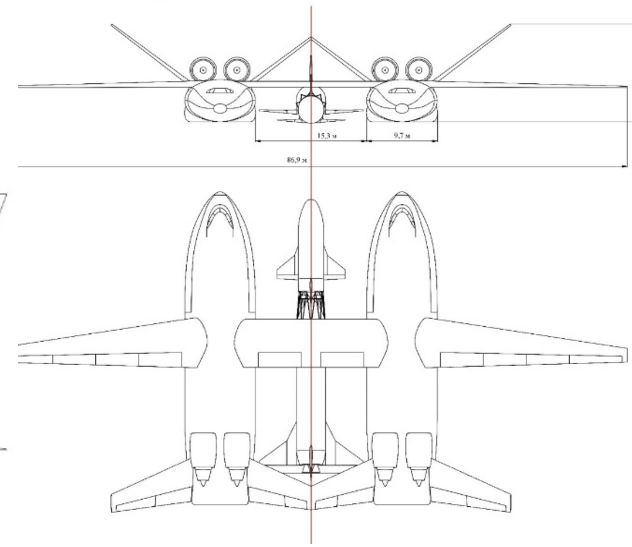
Design

Subsonic carrier base

m_{RS}, t	120
m_{sys}, t	**348**

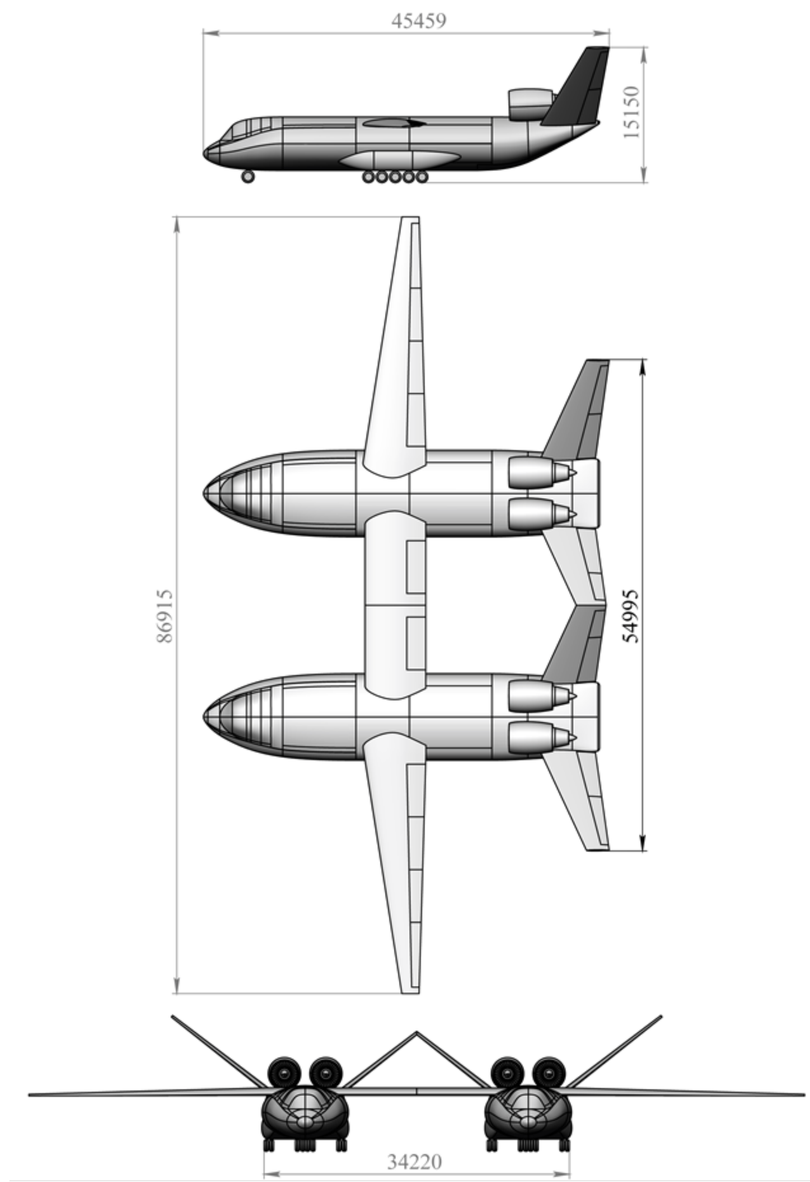


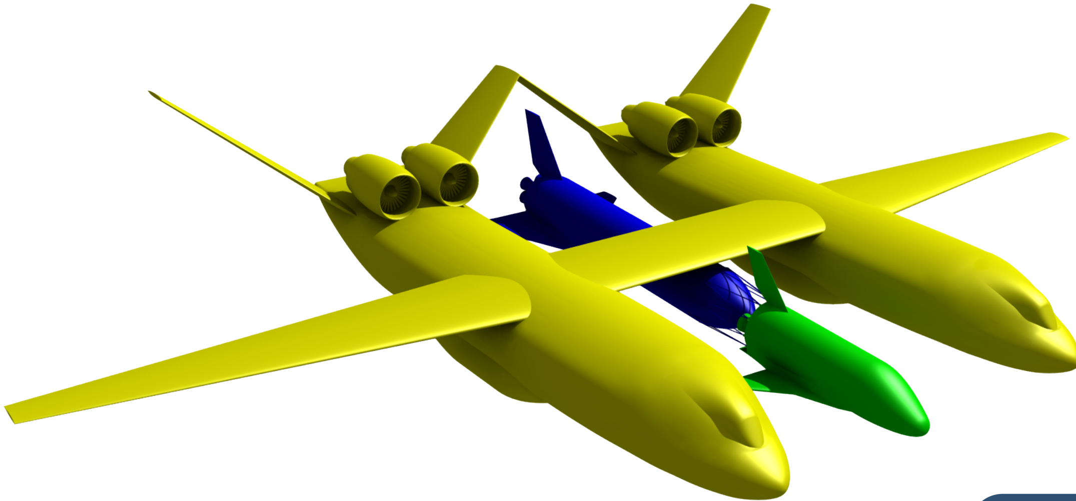


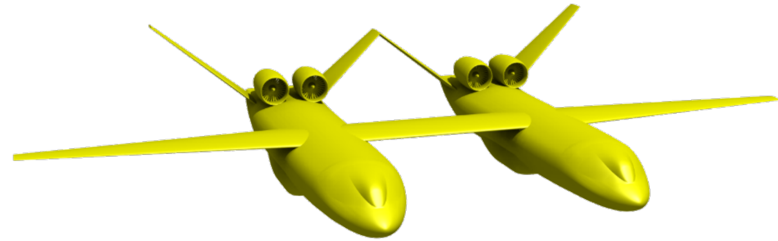


Mass data of double-fuselage Subsonic Carrier

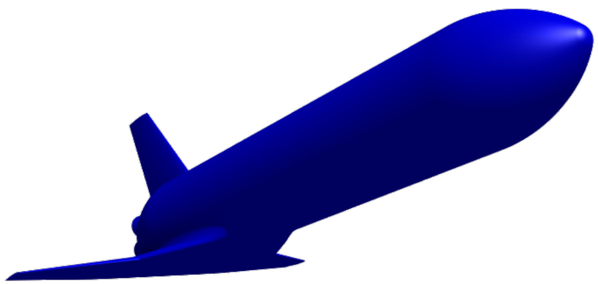
	Mass, t
GLOW incl. passengers & payload (max)	348
Total dry	174
Passengers & pass. equipment	2,8
Payload	120 (34,5%)
Total propellant loading	51,2 (14,7%)
Laden mass	176,8







Carrier: aviation kerosene



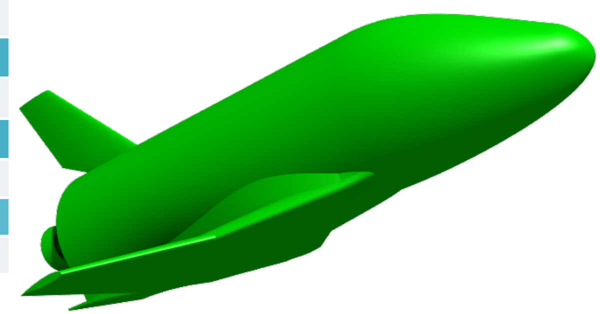
Booster: 1. liquid kerosene and oxygen;

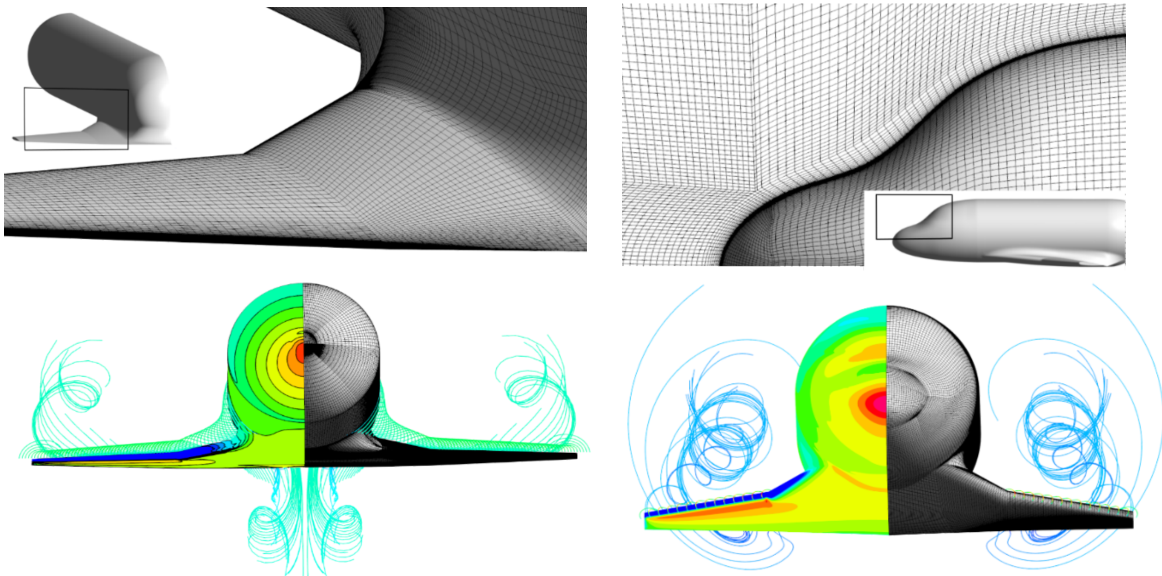
2. liquid methane and oxygen;

3. liquid hydrogen and oxygen

Shuttle: liquid hydrogen and oxygen

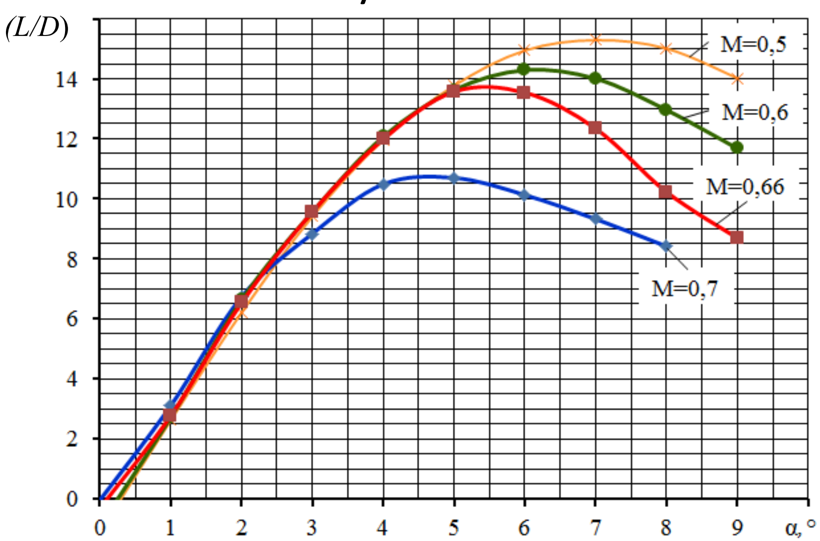
Parameter	Rocket system fuel		
	Kerosene+O_2	Methane+O_2	H_2+O_2
Booster fuel vol., m^3	92,4	112,6	240,5
Booster mass, t	102,2	102,2	99,1
Shuttle mass, t	17,8	17,8	20,9
Payload mass, t	2,2	2,3	3,2
Crew + passengers	2+3	2+3	2+5
Thrust-to-weight ratio RS	1,27	1,23	1,24
Thrust-to-weight ratio Shuttle	0,9	0,89	0,97



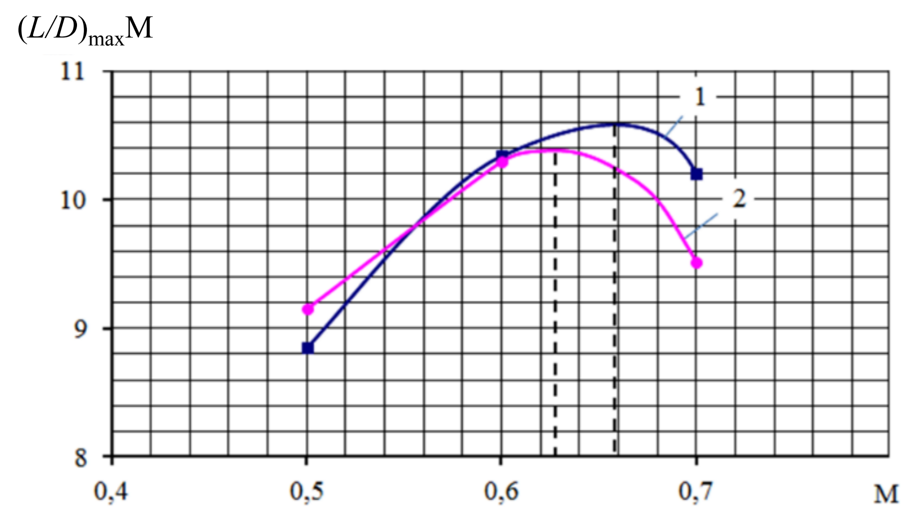


Physics-based simulations and CFD of separate parts and the aerospace system integrally were made with use of massively parallel HPC architectures. M number of cruising flight in comparison single plane with double-fuselage carrier appeared to be the same, otherwise $(L/D)_{max}M$ was decreased on ~12%

Aerodynamic characteristic calculation

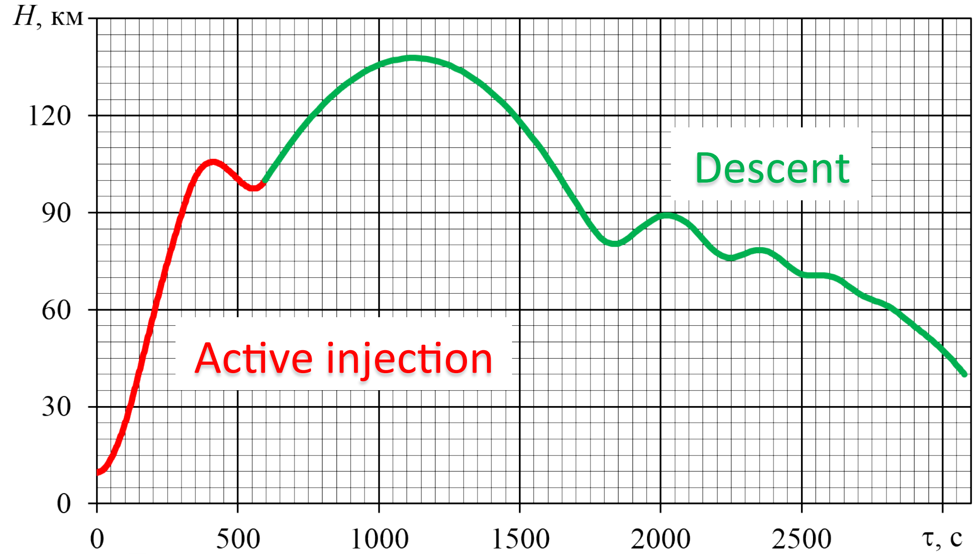


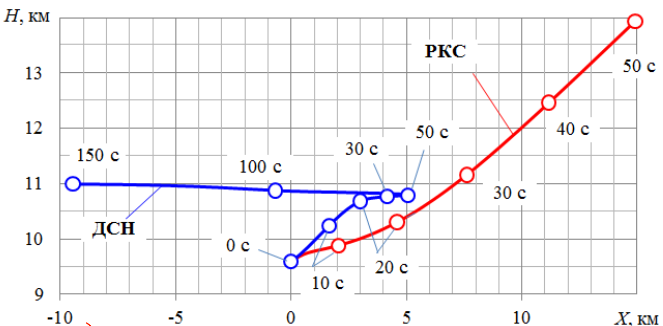
Aerospace system

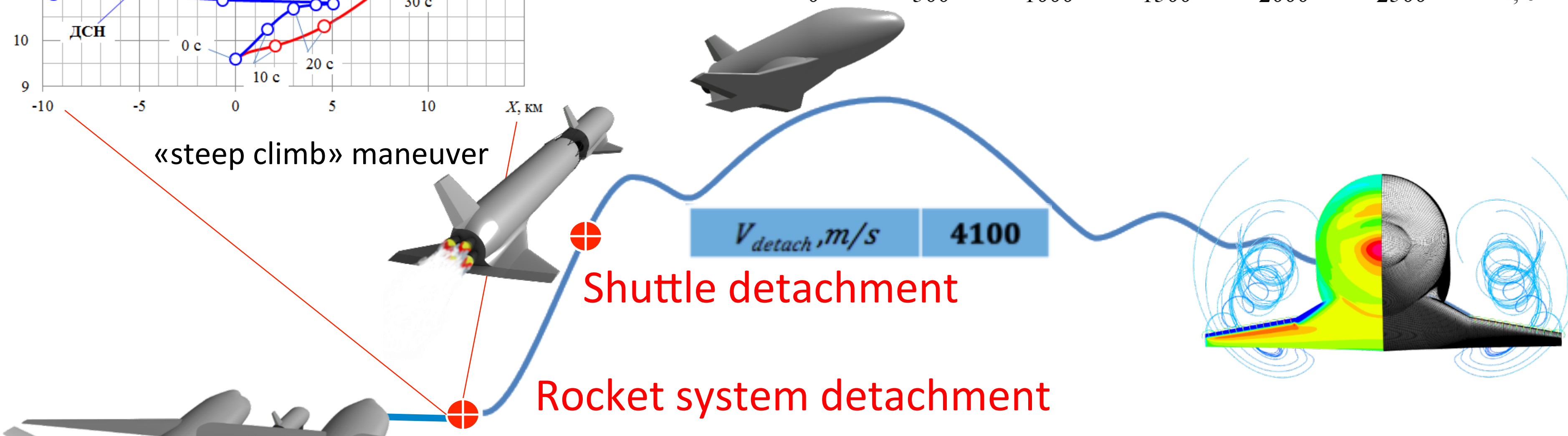


1 – single-fuselage plane; 2 – double-fuselage carrier

Flight path calculation



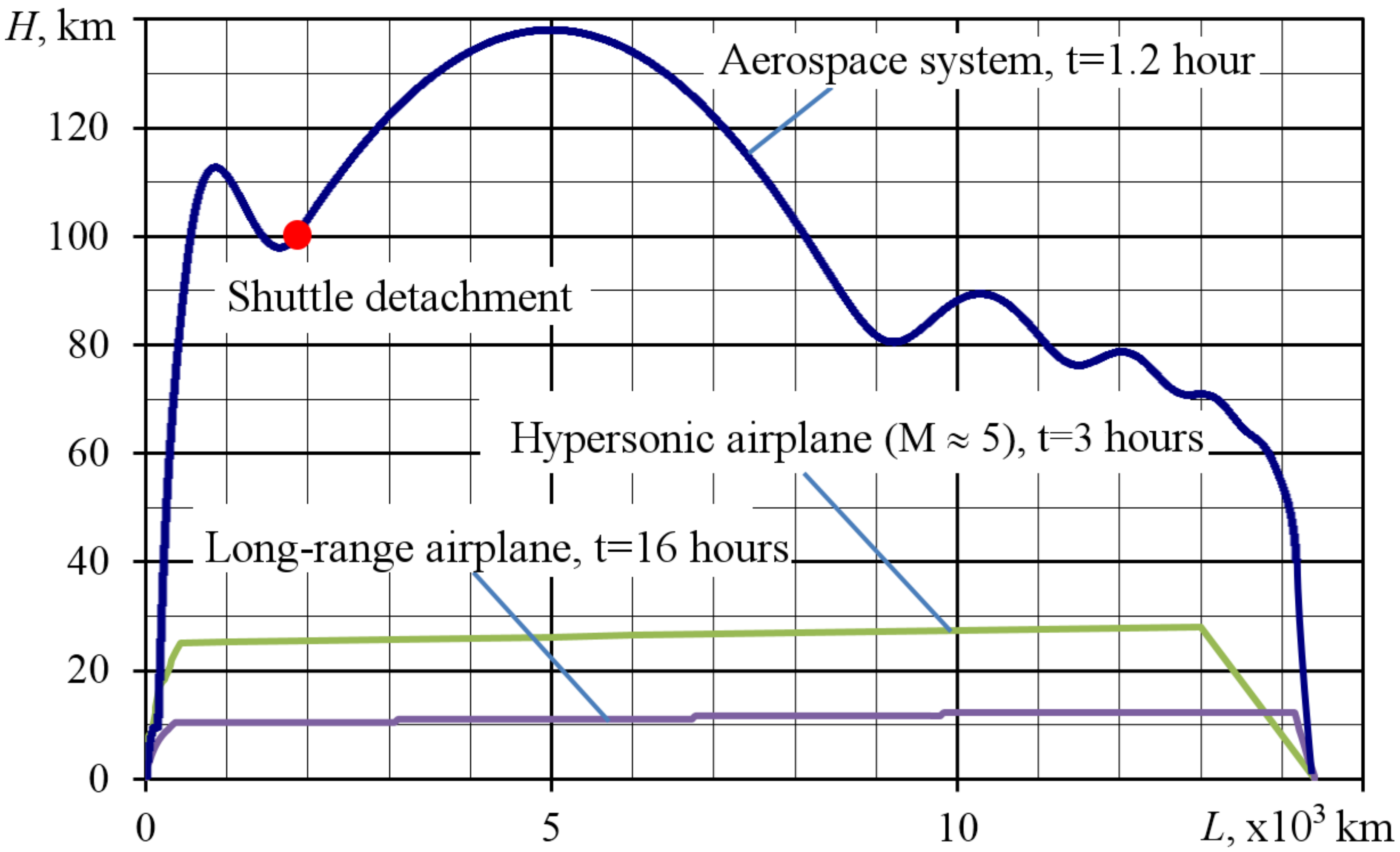




$V_{detach}, m/s$	4100

m_{sys} take off, t	348
M_{detach}	0,63

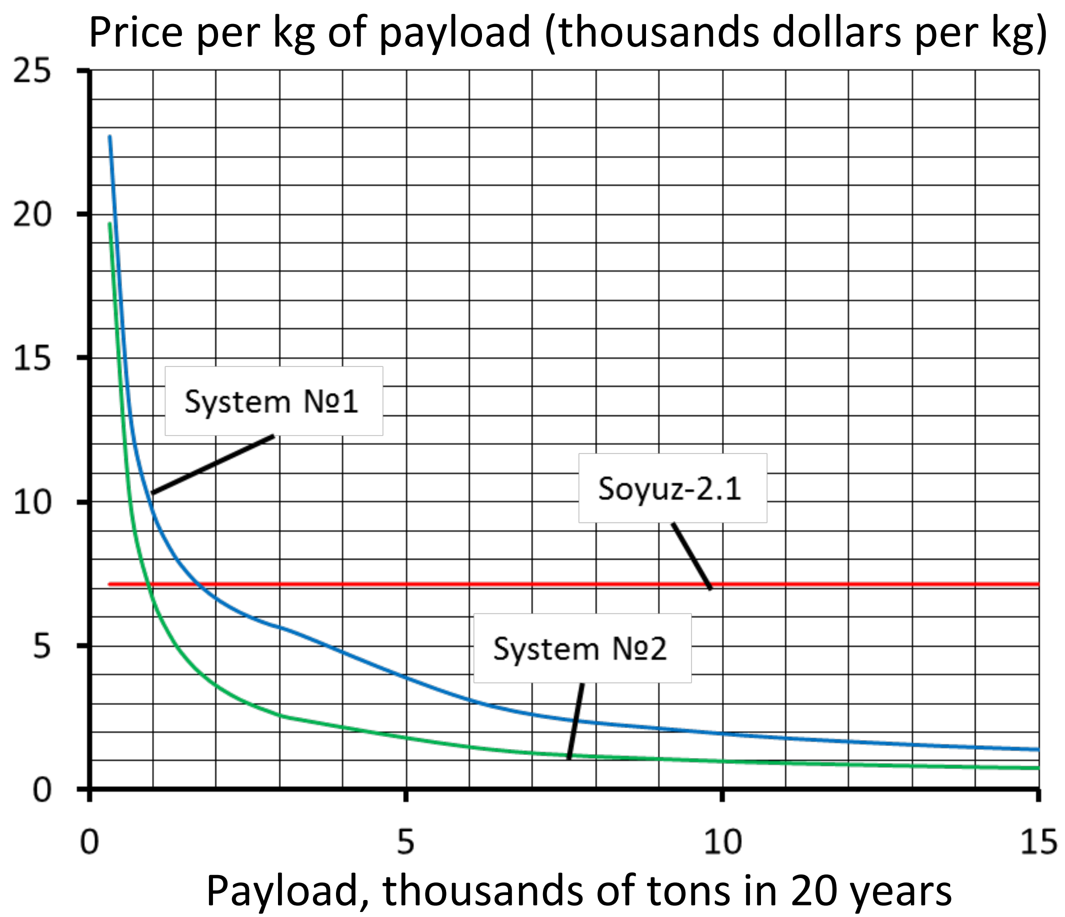
Flight paths of aerospace system, hypersonic and long-range airplane

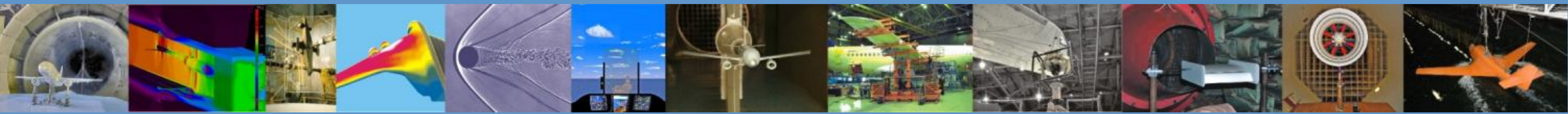


Economic efficiency

Price of payload is primarily determined by construction mass of stages of rocket system. Depending on fuel type of Aerospace system this value and also price transportation to orbit are changing by 5%.

Consequently, in question of alternative fuels we should be guided by technical, ecological and safety considerations.





THANK YOU FOR YOUR ATTENTION!