HLLV Energia
user manual

Yuri Kulchitsky
web-site www.kulch.spb.ru, e-mail postmaster@kulch.spb.ru

October 1, 2009

Disclaimer

This software is provided as it is without any warranty of any kind.

The project has been developed to be used as an add-on for Orbiter Space Flight Simulator by Martin Schweiger (www.orbitersim.com). Designed for Orbiter 2006 Edition, patch 1 (build 060929).

Introduction

HLLV Energia is a Heavy Lift Launch Vehicle Energia (the USSR). The first flight was on May, 15 1987, second (last) flight on November, 15 1988.

ENERGY project is the project which purpose is to create a maximum realistic model of HLLV Energia. The project is based on Russian-language sources.

Some comments on how much realistic the project is. The author realizes that it is impossible to show it completely realistically in all the details. For example, the service tower and the launch site in this project are not realistic (but as true to life as possible). However, everything is authentic, which concerns the following: technical specifications, the sequence of events, the programs of engines control and the separation of stages, etc.

Acknowledgements

I would like to thank the following people:
Vadim Lukashevitch – for his excellent visual models of Energia vehicle (see www.buran.ru).
Alexander Blass – for the *max2msh* export script.
Brian Jones – for night illuminations texture from the *Launch Pad Lights* addon.
Roman Vasiliev (Bloodest) and **Nikita Vtyurin (Thorton)** – for the help in creation of exhaust textures.
My special gratitude is to **Andrey Merkulov** for the mathematical support and to **Aleksander Bochagov** for the help with C++ programming.

Installation

Follow the setup program instructions. After the setup program finish the work you can add some ground observation points. Open the *\Config\Earth.cfg* file and add between `BEGIN_OBSERVER` and `END_OBSERVER` tags the following lines:

```
SRC-Polygon:Command: 101.09703 1.27400 50.00
SRC-Polygon:LS1-bunker: 101.13778 1.33185 1.00
SRC-Polygon:LS1-tower: 101.13796 1.33421 71.91
SRC-Polygon:LS1-antilightning-tower: 101.13886 1.33587 172.10
SRC-Polygon:LS1-blast pit: 101.13778 1.33436 16.90
```

Requirements and limits

Be sure that *ScnEditor* module is activated at *Modules* tab in Orbiter *Launch pad* dialog. The Scenario Editor is required for configuring Energia.

The *Limited fuel* checkbox in *Parameters* tab in *Orbiter Launchpad* dialog should be switched on.

The current version is not full compatible with Orbiters *Flight recorder*.

Current version is based on *Payload Manager* version 2.2.3.0 (http://www.kulch.spb.ru/Eng/PM_project.html). Payload Manager files are included in the installation.

Some scenarios requires the following addons:

1. *Space Tugs*. Can be downloaded from here:
   http://kulch.spb.ru/Eng/downloads.shtml
   and from here:
   http://www.orbithangar.com/searchid.php?ID=1292
2. *Buran3.03Beta* addon by J.Kanios. You can find it here:
   http://www.orbithangar.com/searchid.php?ID=458
3. *CVEL-Buran* by Nerull. Can be downloaded from here:
   http://www.orbithangar.com/searchid.php?ID=755
4. *Buran2* by Mark Petroff. Can be downloaded from here:
   http://www.orbithangar.com/searchid.php?ID=2181
5. *DeltaGlider-IV* by Dan Steph:
   http://orbiter.dansteph.com/index.php
6. *DeltaGlider-HR* by ae7flux:
   http://www.orbithangar.com/searchid.php?ID=2012

This is recommended to download and install the *Baikonur LC 250 (UKSS)*, http://www.orbithangar.com/searchid.php?ID=4186

Note that *Buran3.03Beta* by J.Kanios and *Buran2* by Mark Petroff are NOT compatible, please install only the one.

Quick launch

Start Orbiter and select a scenario *\ENERGY project\SkyLinkSat satellite\Launching SkyLinkSat.* (Warning! This scenario requires the Space Tugs addon installed).

There is Energia ready for launching and carrying a Buran-T container as a payload. Buran-T carries inside an orbital space tug Smerch with the big space platform of communication – SkyLinkSat. The task is to perform the orbital insertion of SkyLinkSat at a geostationary orbit (radius of geostationary orbit is – 42163.8 km). The launch autopilot of Energia is tuned, so you need only push the *START* button on the control dialog (or S on keyboard) to start your mission (it is also recommended to switch the view using F1). After 30-second launch preparation the rocket starts and you do not need to perform any actions until the separation of the Buran-T container. (Certainly, if you want to carry out a manual flight, you should press V key to switch off the autopilot, but only after the rocket reaches 200 meters altitude above the launch site).

After the Buran-T disclosure and the separation of a Smerch tug together with SkyLinkSat satellite, try to put them into a geostationary orbit. Use J-key to jettison SkyLinkSat. After the jettison the satellite automatically deploys and obtains the vertical orientation. After the SkyLinkSat deployment you can switch back to Smerch (F3-key) and carry out a deorbit burn, as there should be enough fuel left. Say "NO!" to any orbital trash!

1. Energia does not give the full orbital speed to its cargo.
2. Remember, that in this scenario a Smerch tug has only 10 engine starts.

3. During an Energia autopilot active flight you cannot use time acceleration.
4. Smerch, Buran-T and SkyLinkSat are the parts of a Space Tugs addon. So you can learn more from Space Tugs addon manual. Use the menu *Start – All programs – Kulch's Orbiter addons – Space Tugs – Manual in English*. It is a pdf-file.

Buran scenarios
(requires *Buran3.03Beta* addon by J.Kanios, *CVEL-Buran* by Nerull or *Buran2* by Mark Petroff)
\Buran\... – in this folder you can find the scenarios with soviet shuttle Buran. Be attentive – Buran vessel is not included in ENERGY project distribution and should be installed separately.

Note that *Buran3.03Beta* by J.Kanios and *Buran2* by Mark Petroff are NOT compatible, please install only the one.

DeltaGlider, DeltaGlider-III and DeltaGlider-HR scenarios
\DeltaGliders\... folder contains scenarios with the default DeltaGlider, DeltaGlider-III and DeltaGlider-HR spaceships. This scenarios requires the *DeltaGlider-III* addon by Dan Steph and *DeltaGlider-HR* addon by ae7flux.

Deep Star scenarios
\Deep Star spacecraft\... – in this folder you can find the scenarios with Deep Star exploration space ship (fictitious). This scenarios requires the Space Tugs addon installed.

HLLV Energia desciption

The heavy rocket Energia has been developed for delivering cargoes weighing about 100-110 tons to a low Earth orbit. The rocket is universal because it can deliver various cargoes in terms of theirdimensions and distribution of weight.

General specifications:

Full starting weight	2419 tons
Including payload	105 tons
Overall dimensions	length 60 m, max diam 18 m
Full thrust on start	3,582 tf
Maximum G-factor	2.95

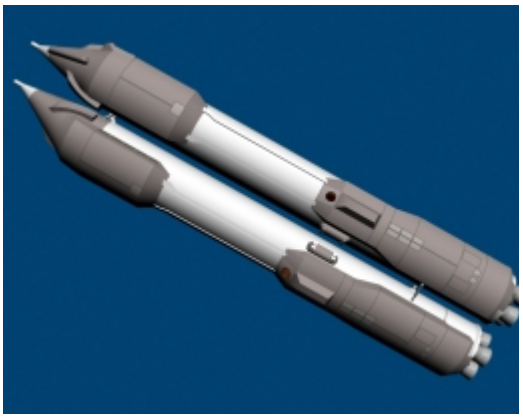
The rocket is grouped following the longitudinal arrangement of stages with a lateral arrangement of a payload.

First stage - block A

The first stage consists of 4 reusable rocket blocks (block A), fixed around the second stage central block in pairs.

Block A specifications:

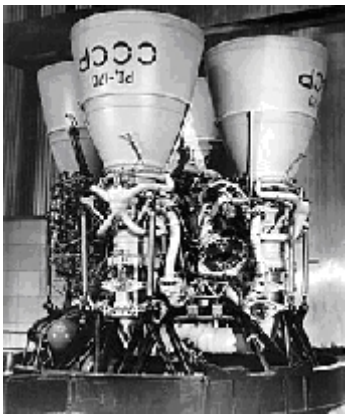
Dry weight	About 62 tons
Fuel weight	310 tons (Lox/Kerosene)
Dimensions	Length 38.3 m, diam 3.9 m



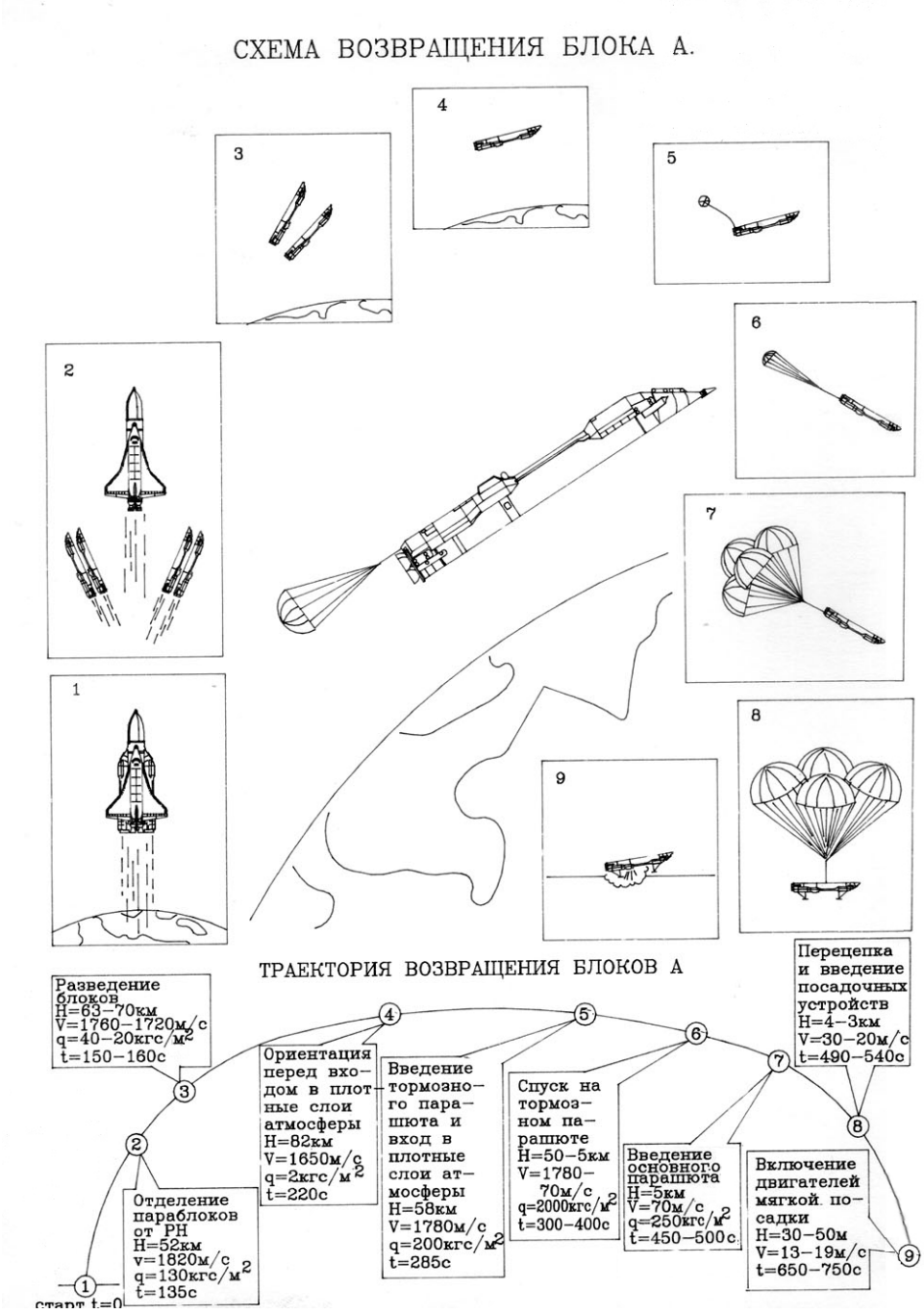
At the first stage one four-chamber engine RD-170 is mounted.

RD-170 specifications:

Thrust at sea level	740.5 tf
Thrust in vacuum	806 tf
Fuel	LOx/Kerosene
Burn time	140-150 s



First stage saving sequence



Legend:

1 Launch
T = 0

2 First stage separation by pairs
T = 135 s, H = 52 km, V = 1820 m/s

3 Pairs separation
T = 150-160 s, H = 63-70 km, V = 1760-1720 m/s

4 Orientation before reentry
T = 220 s, H = 82 km, V = 1650 m/s

5 Brake chute enabling
T = 285 s, H = 58 km, V = 1780 m/s

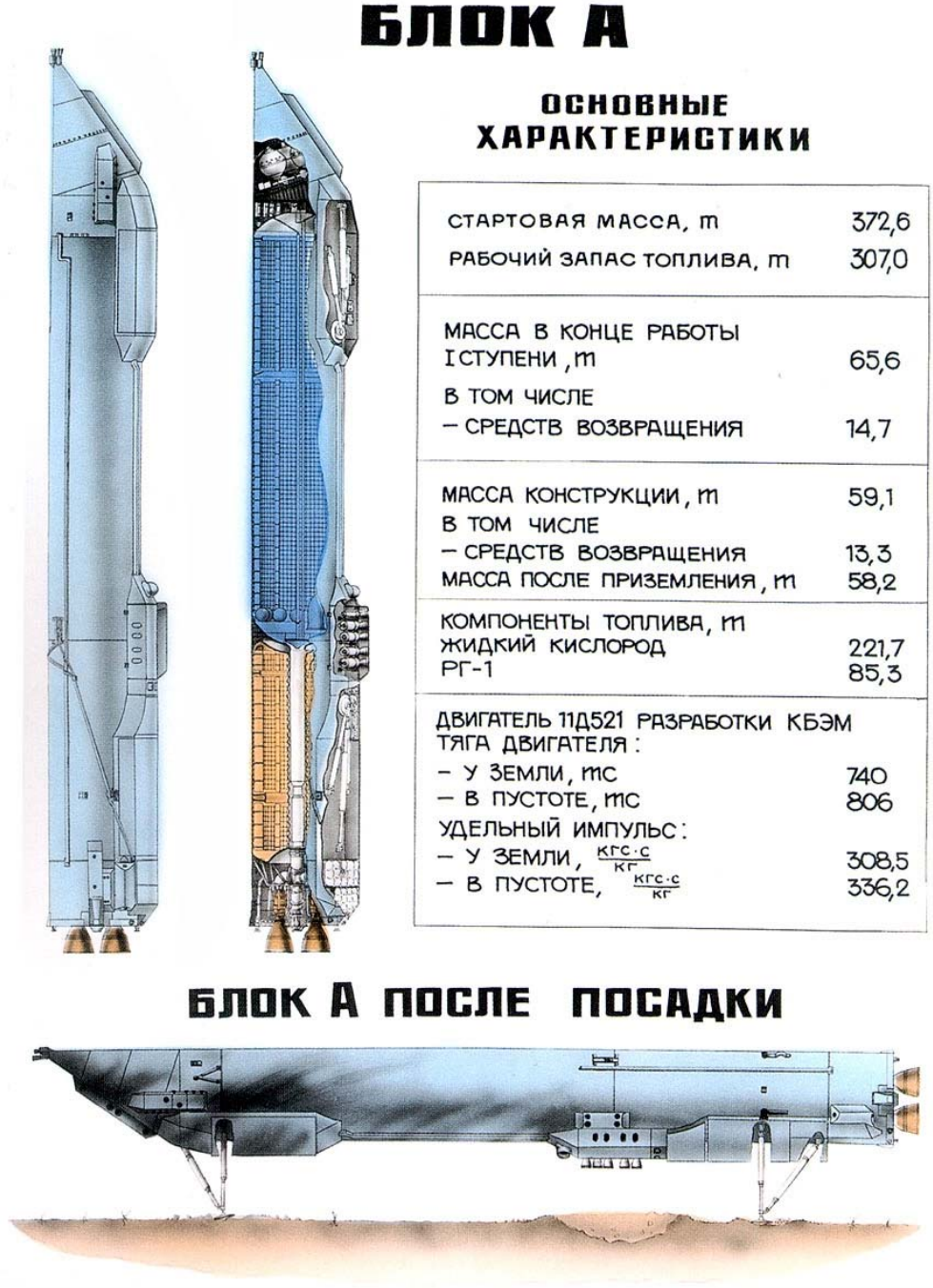
6 Descending
T = 300-400 s, H = 50-5 km, V = 1780-70 m/s

7 Main chute enabling
T = 450-500 s, H = 5 km, V = 70 m/s

8 Main chute reattaching, landing gear down
T = 490-540 s, H = 4-3 km, V = 30-20 m/s

9 Landing engines enabling
T = 650-750 s, H = 30-50 m, V = 13-19 m/s

Modelling of the 1-st stage landing system is based on this picture:



Translation:

Starting mass, t	372.6
Working fuel mass, t	307.0
Mass on separation, t	65.6
including landing systems mass	14.7
Dry mass on separation, t	59.1
including landing systems mass, t	13.3
Mass after landing, t	58.2
Liquid oxigen mass, t	221.7
Fuel (RG-1) mass, t	85.3

Second stage - block C
The second stage is a central non-reusable rocket block (block C).

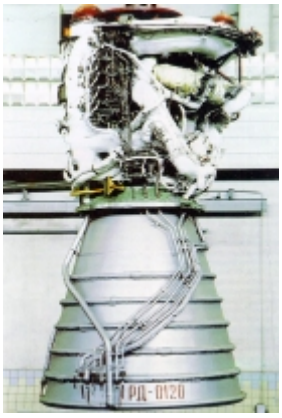
Block C specifications:

Dry weight	78-86 tons
Fuel weight	704 tons (LOx/LH2)
Dimensions	length 58.1 m, diam 7.7 m

At the second stage four engines RD-0120 are mounted.

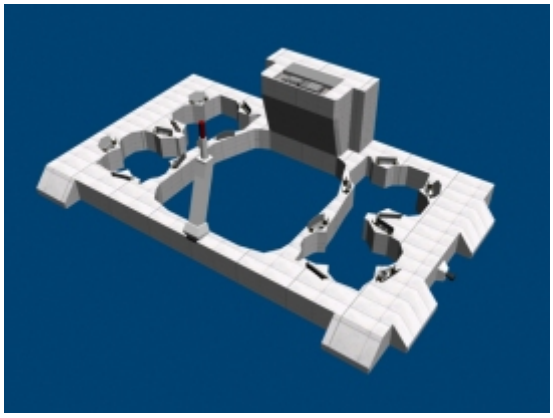
RD-0120 specifications:

Thrust at sea level	142.5 tf
Thrust in vacuum	200 tf
Fuel	LOx/LH2
Burn time	480-500 s

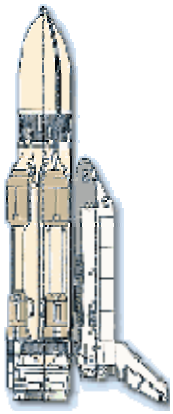


Ground stage - Block Z

Block Z is the intermediate module which ensures connection between the ground communications and the rocket. Block Z is reusable.



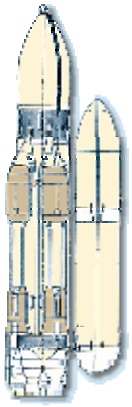
Payload variants



1. Any payload weighing about 105 tons

For example, Buran. Theoretically instead of Buran any other cargo (including an oversized one) can be mounted.

The only condition is that a payload should have its own engine to perform a complete orbit insertion, as it is necessary that Energia does not give the full orbital speed to its cargo.



2. Any payload in special container equipped with an upper stage

This concept (the former name of it is Buran-T) is based on a special aerodynamic container. Basically there exist three variants:

1. Buran-T + space tug DM + payload

Payload specifications:
PL volume is about 830 cubic meters (35 m length and 5.5 m diameter). PL weight is 88 tons being put into LEO 200 km high and 81 tons into 600 km high Earth circular orbit.

2. Buran-T + space tug Smerch + payload

Payload specifications:
PL volume is about 550 cubic meters (23.5 m length and 5.5 m diameter). PL weight is 18-19 tons being put into a GEO orbit, 23-29 tons at the Moon Lagrange point and 21.5-23 tons into a near Moon orbit.

3. Buran-T + space tug Smerch + space tug DM + payload. It is a two-stage tug system

Payload specifications:
PL volume is about 460 cubic meters (19.5 m length and 5.5 m diameter). PL weight is 26-28 tons being put into the Mars trajectory, about 15 tons into a near Mars orbit and 5-6 tons into the Sun trajectory with a tour round the Jupiter.

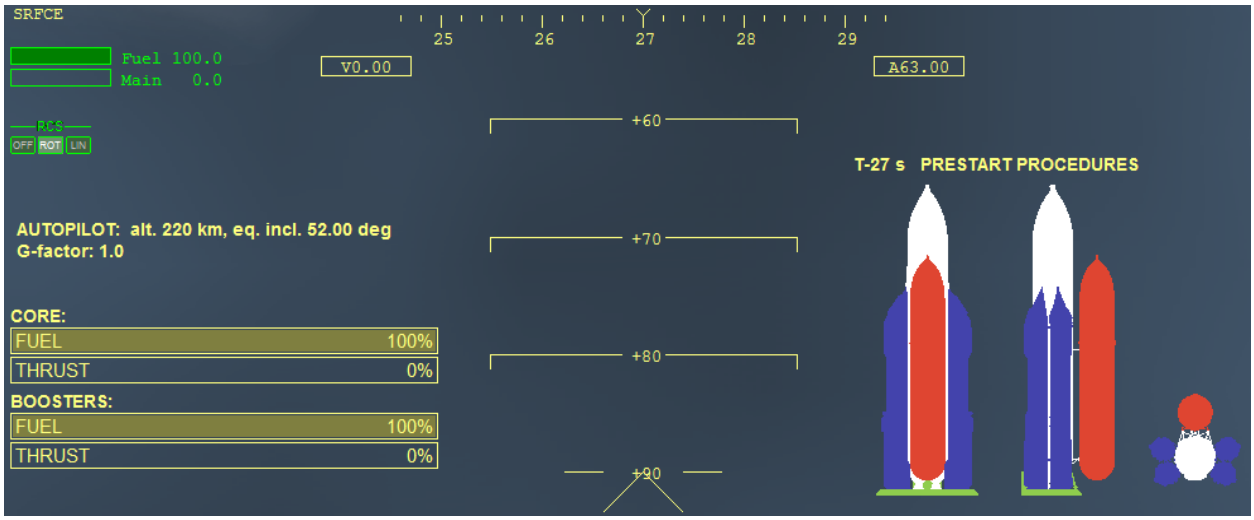
Flight events table

In ENERGY project the Energia model has a high automation level. Even using manual flight you can't control thrust level.

Time, s	Event description	
T-30	Beginning of prelaunch preparation	Launch cancel is possible
T-25	Service platforms removal	
T-15	Engines gimball system testing	
T-9	Abort decision point, the beginning of irreversible starting procedures	
T-8	C-block engines ignition, program increase of thrust	Fully automatic zone
T-1	A-block engines ignition, program increase of thrust	
T+0	Cable platform removal, disclosing of locks, signal of rise, Z-block cable-trunk removal, closing Z-block electro- pneumatic and hydraulic sockets	
T+9	Start zone is clear. Lifting to 200 m altitude. Possibility of autopilot disabling.	
T+30	Beginning of C-block engines thrust decrease to 70% of max level for dynamic pressure and G-factor decreasing	
T+37	Lifting to altitude 5,000 m. Possibility of payload jettison	
T+39	Beginning of A-blocks engines thrust decrease to 70% of max level	
T+77	Increase of all engines to 100%	
T+140	Applying finish procedures for A-blocks engines, decreasing thrust to 50 %	
T+149	Cutting off 10A and 30A A-blocks engines	Manual control of flight is possible Abort of mission is possible
T+149.15	Cutting off 20A and 40A A-blocks engines	
T+149.20	Separation of A-blocks pairs, solid boosters ignition (A-group boosters)	
T+149.60	Next solid boosters ignition (B-group boosters)	
T+179.2	Separation of pairs into single A-blocks, ignition of solid boosters (C-group)	
T+350	Beginning of C-block engines thrust decreasing in order to provide the required G-factor	
T+402	Applying finish procedures for C-blocks engines, decreasing thrust to 50 %	
T+410	Cutting off 1 and 3 C-blocks engines	
T+410.2	Cutting off 2 and 4 C-blocks engines	
T+425	Beginning of payload (payloads) separation	

HUD

To provide some flight information Energia is equipped with a special HUD, see the picture:



On left side:

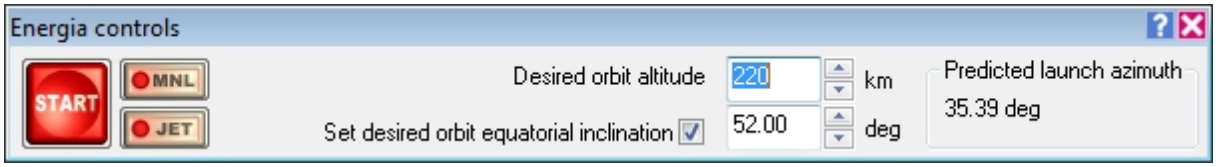
1. The autopilot settings
2. G-meter
3. Fuel and thrust status for 1-st and 2-nd stages
4. Error messages

On right side:

1. Flight timer
2. Current status message
3. Stage status

Control dialog

All what you need for control Energia is a *Control dialog*, see picture:



To open Control dialog press Ctrl+space keys (make sure that control focus is on Energia vessel, use F3-key to switch the control focus).

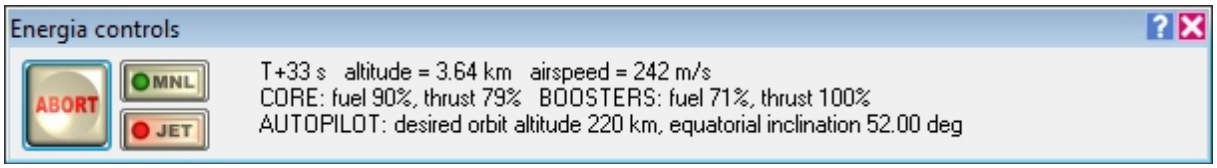
Before launching you can set the altitude and equatorial inclination of desired orbit. If *Set desired orbit equatorial inclination* checkbox is not checked the autopilot will be tuned on minimal orbit inclination for current launch site latitude. *Predicted launch azimuth* box shows the heading for trajectory which provide desired equatorial orbit inclination.

To start the launch sequence just hit the red *START* button.

Start can be cancelled, the possible error messages are:

1. From autopilot:
   Invalid desired equatorial inclination – the desired orbit equatorial inclination can't be provided with present launch point equatorial latitude.
2. From rocket:
   No payload present – the rocket can't be launched without payload(s).
   Too light payload – the minimal payload(s) mass is 22 tons.
   Too heavy payload – the maximal payload(s) mass is calculated to provide the relation of engines thrust to full starting weight not less than 1.25.

During the flight the Control dialog shows flight timer, stages status and some flight information:



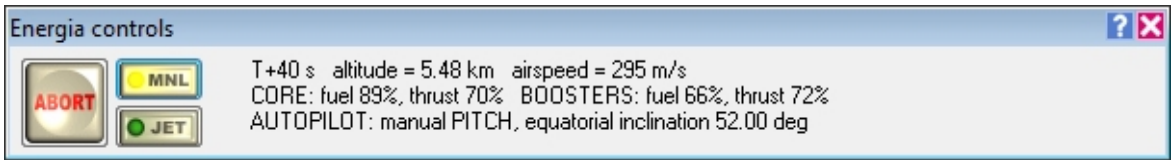
To abort your mission press the *ABORT* button. The abort sequence is:

1. Dumping the oxidizer from 1-st stage. Shutting down the 1-st stage engines.
2. Separating the 1-st stage.
3. Shutting down the 2-nd stage engines.
4. Separating the payload(s).

In addition you can:

new !

1. Switch autopilot to manual PITCH mode by pressing *MNL* button (only if button highlighted with green dot). With this mode you can control pitch manually, but yaw and roll angles are still under autopilot. Mode indicates by yellow dot on *MNL* button:



2. Switch off autopilot by pressing *MNL* button second time (only if button highlighted with green or yellow dot).
3. Start payloads jettison sequence by pressing *JET* button (only if button highlighted with green dot).

Keyboard interface

S	Begin launch preparation. Abort launch procedure or mission.
V	First pressing – switch autopilot to manual PITCH mode. Second pressing – switch autopilot off. Only on alitude more than 200 m above launch pad elevation.
J	Manual jettison payload(s). Only on altitude more than 5000 m.
Ctrl+space	Open Control dialog.

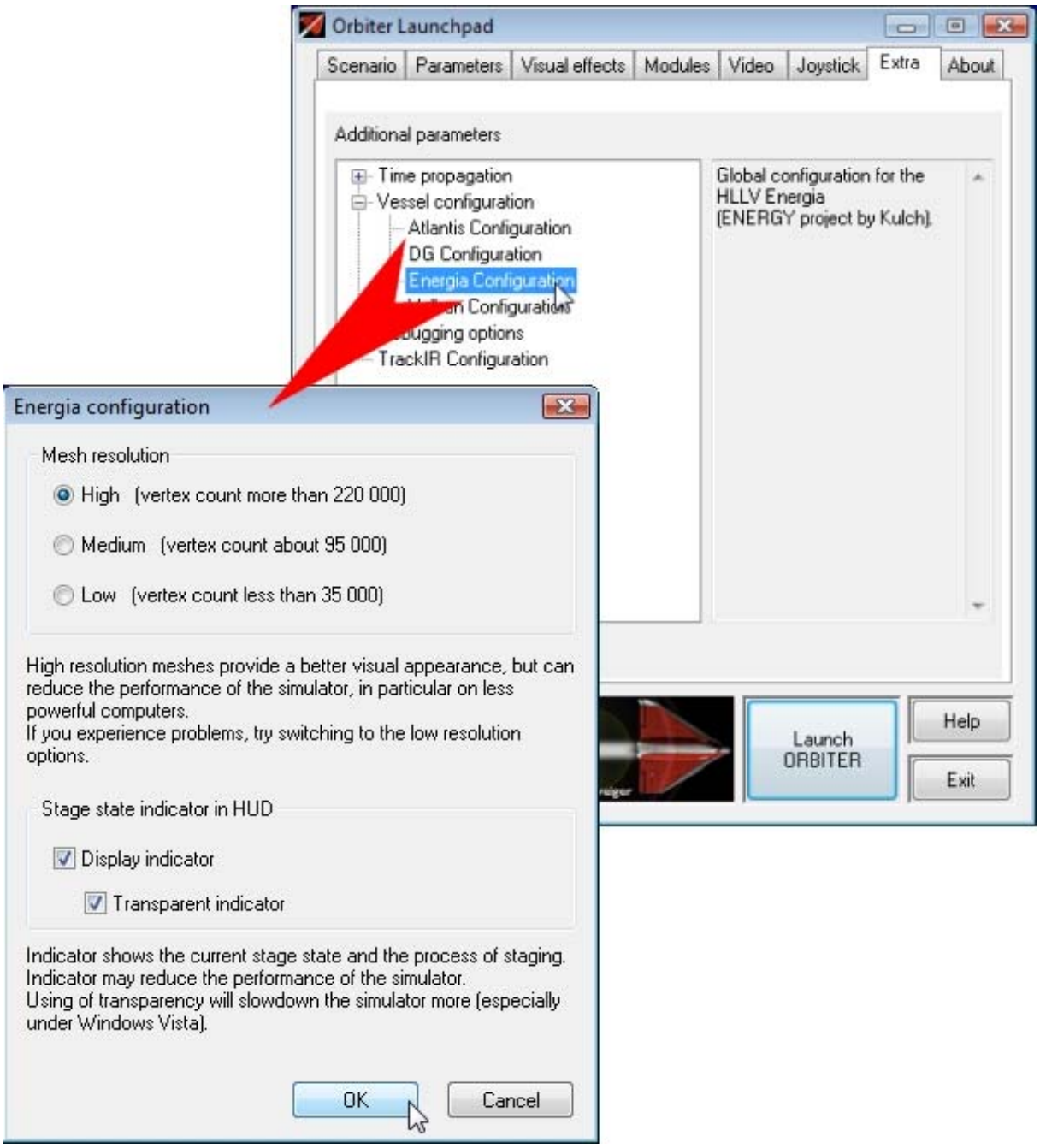
new !

Performance settings

The ENERGY project package has a three mesh resolution modes: low, medium and high. By default the mesh resolution is *high*.

The simulation performance in cockpit view depend of HUD complexity. You can improve performance by disabling of Stage state indicator or by switching it's transparency off (useful under Windows Vista).

Open *Extra* tab on Orbiter *Launch pad dialog*. In *Additional parameters* box select *Vessel configuration – Energia Configuration* node and double click it to open the *Energia configuration* dialog. *Mesh resolution* radiobuttons allows you to select visual model complexity. With *Stage state indicator in HUD* checkboxes you can set up the staging indicator.

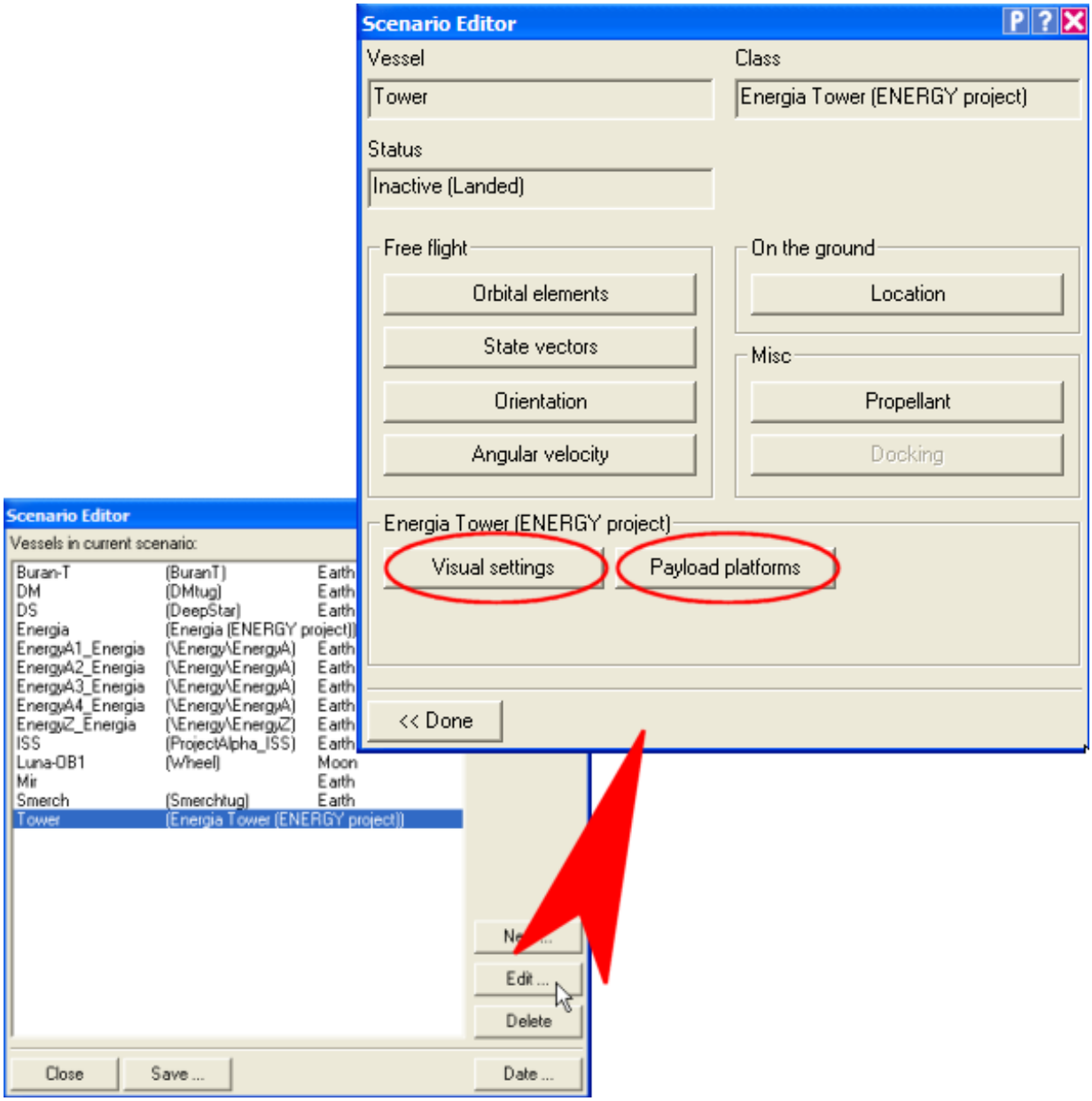


Configuring

Energia is compatible with Orbiter Scenario Editor (read more about Scenario Editor in *Doc\ScenarioEditor.pdf* manual). You can change some Energia setting using Scenario Editor.

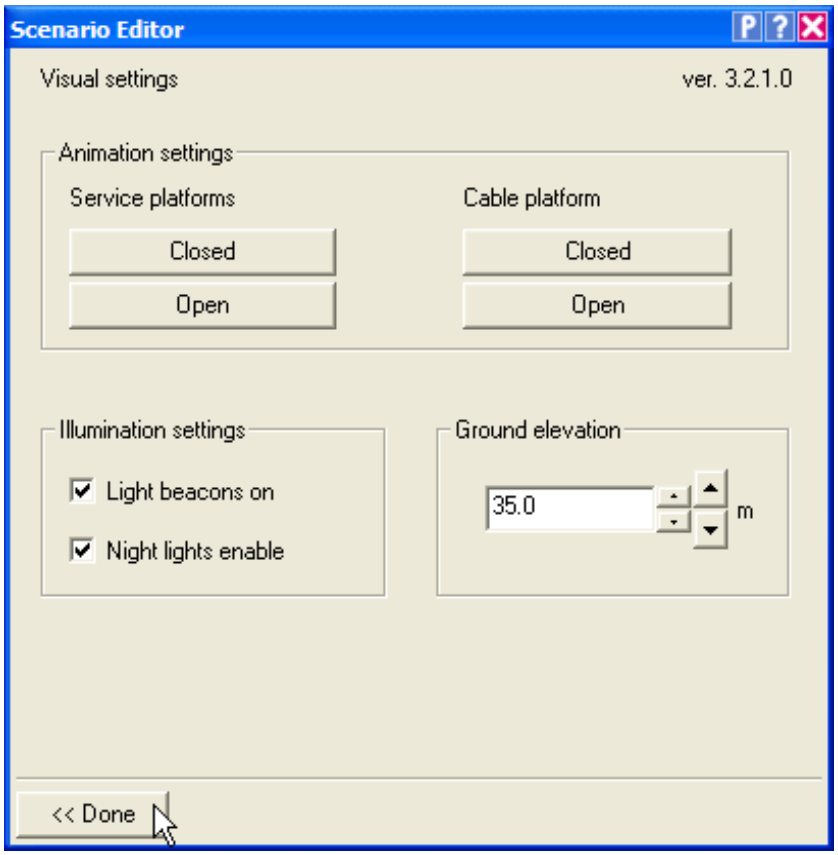
Configuring Energia service tower

Open Scenario Editor and select the *Energia service tower* vessel (*Tower* for example, see picture). Click the *Edit...* button:



1. Visual settings

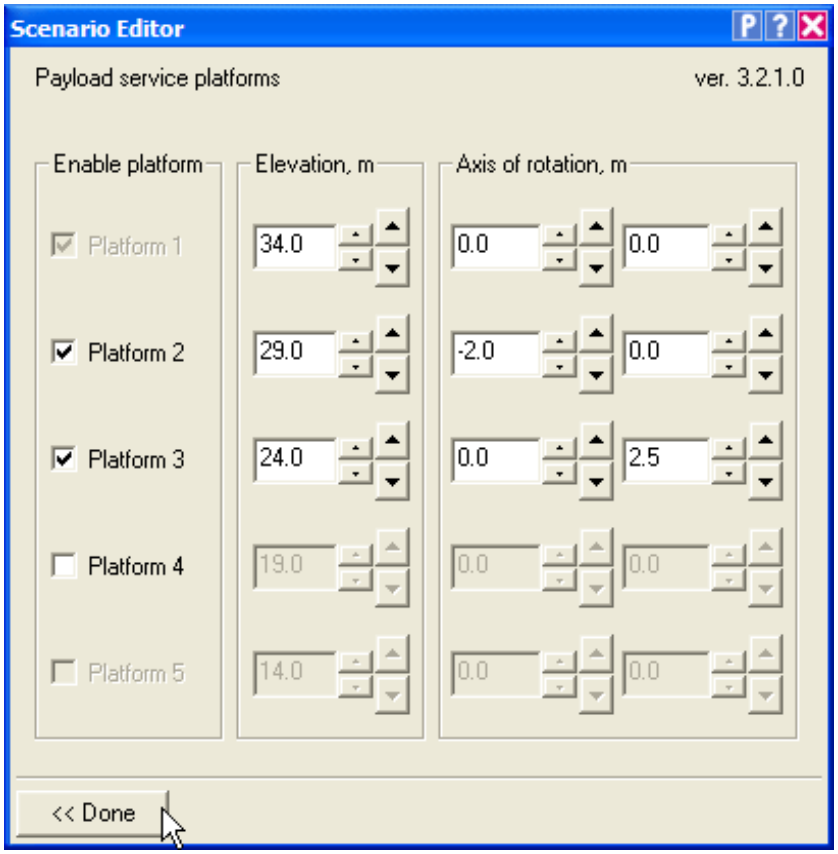
Visual settings page allows you to change the visual appearance of the tower:



In *Animation settings* section you can open or close the tower's platforms. Also you can change *Illumination settings* – switch on or off the night lights and beacons. Night lights shine only at night. *Ground elevation* box allows you to define the tower elevation above the ground level (maximum value is 52 m).

2. Payload platforms

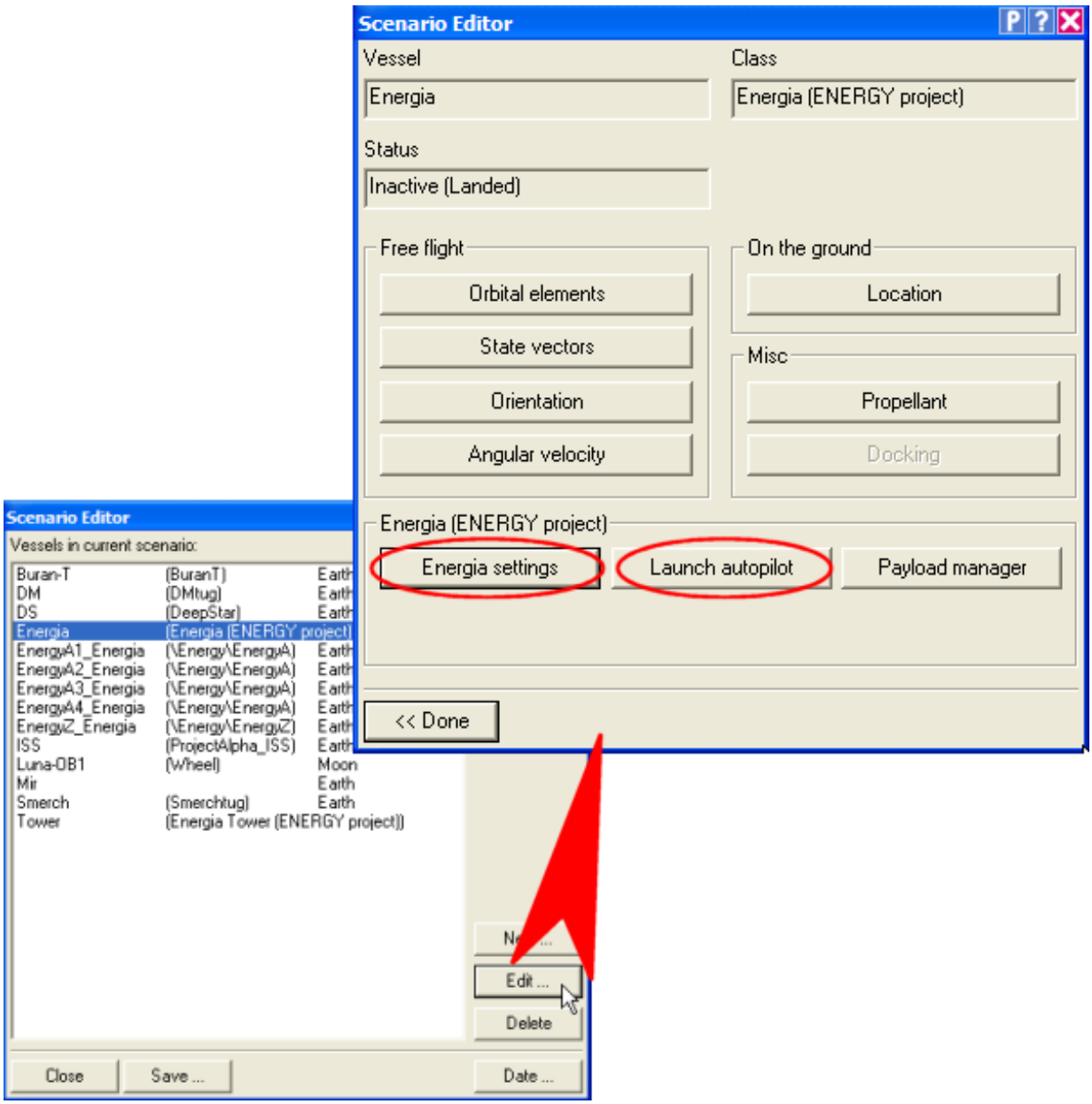
Sometimes you need to place tower's payload platform(s) more accurately.



Here you can define the number of payload platforms (in case the Energia carries more than one payload) the elevation and location for the point of rotation for each platform separately.

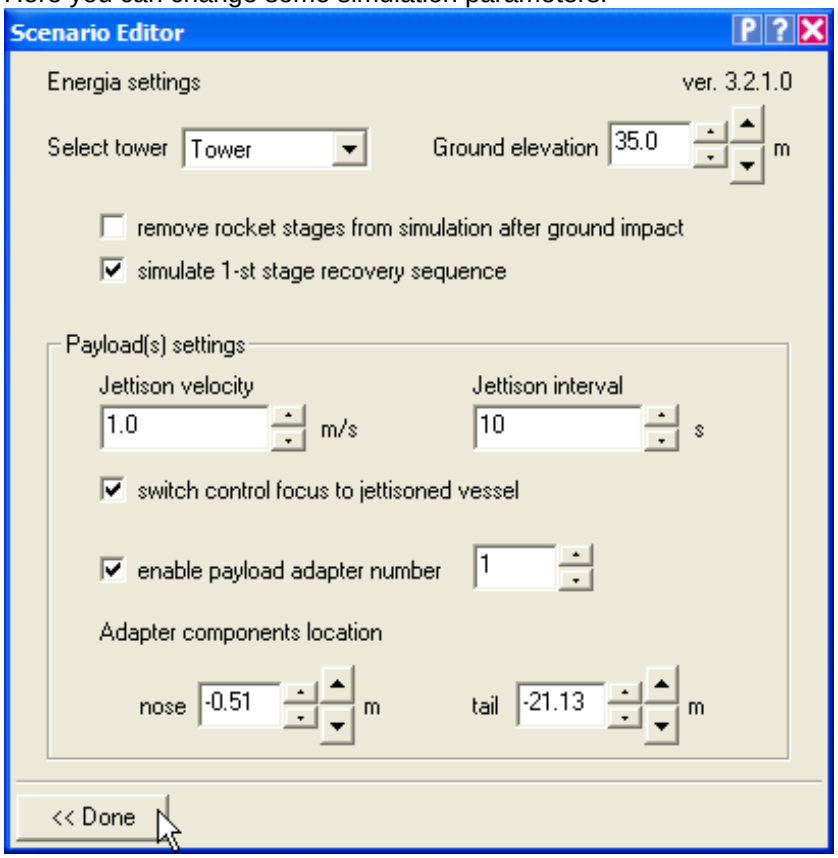
Configuring Energia

Open Scenario Editor and select the Energia vessel (*Energia* in example on the picture below). Click the *Edit...* button:



1. Energia settings

Here you can change some simulation parameters:



In *Select tower* combo you can define the service tower linked to your Energia. During prestart preparation Energia will send signals to this tower to control the process of tower's platforms removing. This list contains only *Energia Tower* vessels which are currently present in simulation.

If you want to create the scenario without service tower just select *no tower* entry.

Ground elevation box allows you to define the rocket elevation above the ground level (maximum value is 52 m). To provide realistic visual appearance set the same elevation as for Energia's tower.

If *remove rocket stages from simulation after ground impact* checkbox is checked the 1-st and 2-nd rocket stages will be deleted from simulation after falling on the ground.

Be careful with *remove rocket stages from simulation after ground impact* checkbox. Some addons can't work properly in case of unexpected deleting vessels from simulation.

During an Energia 1-st stage reentry and parachutes landing you cannot use the time acceleration. It can seem inconvenient. So you can disable the simulation of 1-st stage soft landing. Just uncheck the *simulate 1-st stage recovery sequence* checkbox.

In *Payload(s) settings* section you can tune the payload jettison and payload adapters. Velocity which payload vessel receives during jettison is defined in *Jettison velocity* box (the minimum value is 0 m/s, maximum value is 10 m/s).

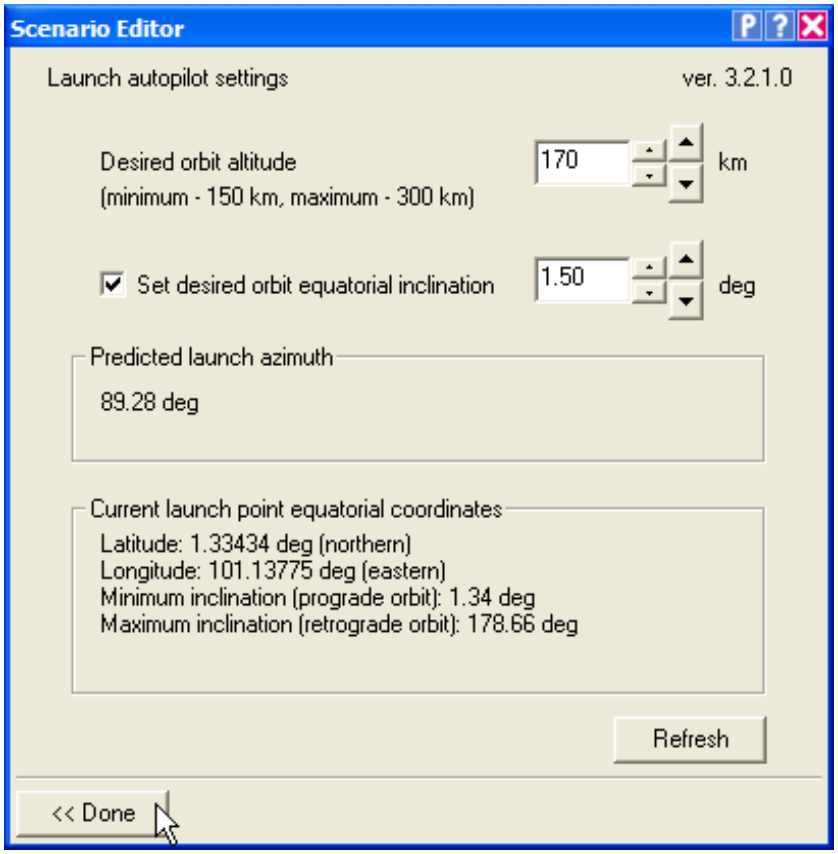
The time interval between payloads separation (in case the Energia carries more than one payload) defines the *Jettison interval* box (the minimum interval is 5 s and maximum is 30 s).

After payload separation the control focus can be switched to a payload vessel. It is determined by *switch control focus to jettisoned vessel* checkbox.

Energia has at least one pair of payload adapters – nose and tail. You can define position of adapter in *Adapter components location* boxes – for nose and tail component separately. If you have added one more payload you can enable one more adapter. Set number of adapter to 2 and check on the *enable payload adapter number* checkbox. After that you can shift the nose and tail components as you need.

2. Launch autopilot

On this page you can tune the autopilot:



This is the orbital insertion autopilot. You can set the altitude and equatorial inclination for your desired orbit. The minimal orbit altitude is 150 km and the maximal orbit altitude is 300 km.

Remember – Energia does not give the full orbital speed to its cargo. The payload should complete the orbital insertion with its own thrusters.

The possible value of equatorial inclination is depends of launch pad latitude. If the desired equatorial inclination is less than launch pad latitude the autopilot will show the error message and mission will be aborted.

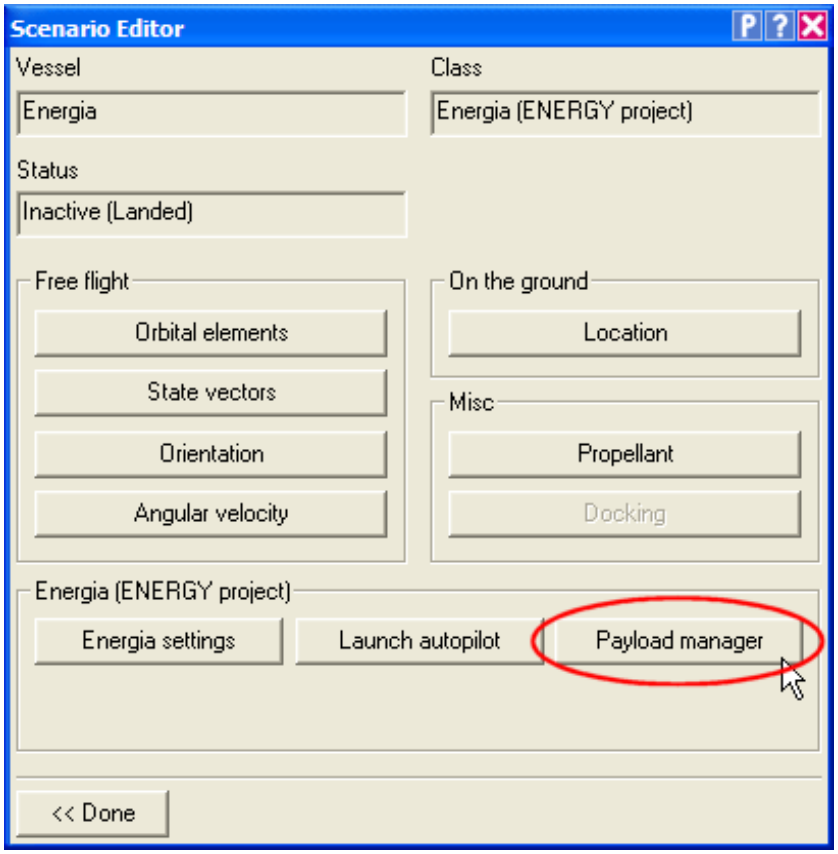
If the *Set desired orbit equatorial inclination* checkbox is not checked the autopilot will be tuned on minimal orbit inclination for current launch site latitude. The *Predicted launch azimuth* box shows the heading for trajectory which provide the desired equatorial orbit inclination.

If you have changed the rocket location, press the *Refresh* button to update dialog data.

When the Energia is in active flight please don't change the date and time settings in Scenario Editor, it can result in undefined behaviour.

Payload managment

Energia is a universal vehicle. You can select any another vessel as a payload for Energia. Payload setup is provided by *Payload Manager*. You can access it via *Scenario Editor* in the Energia configuration page:



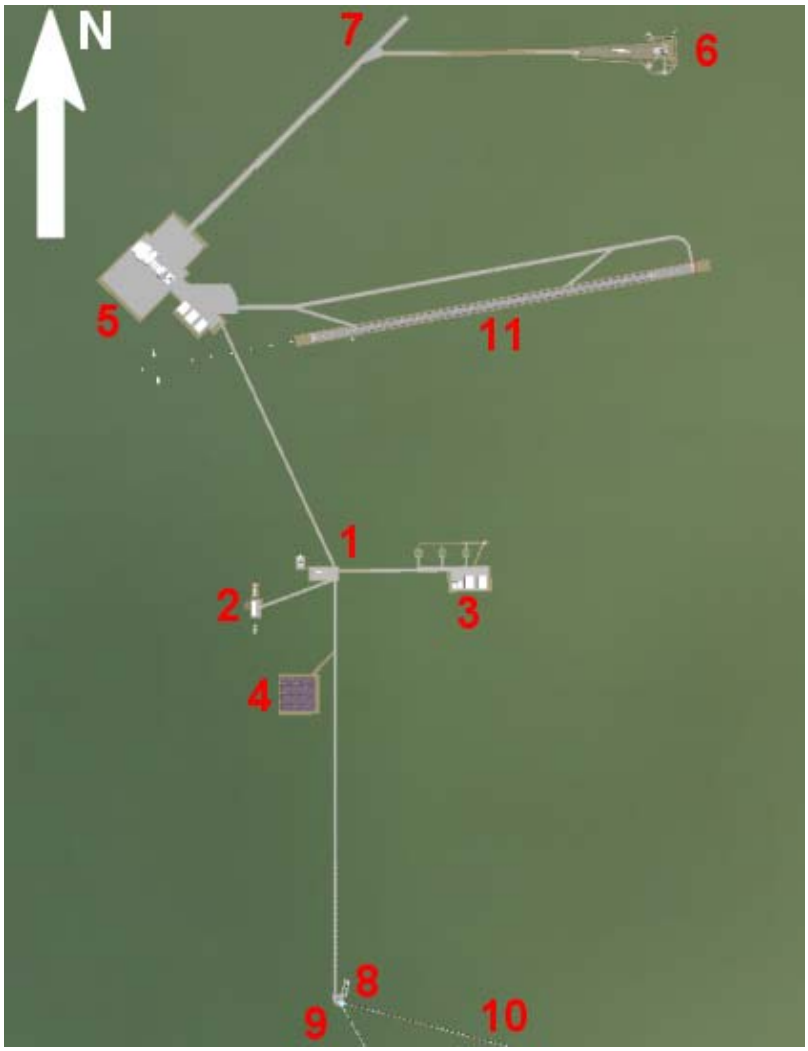
How to use the Payload Manager read the manual *\Doc\Payload Manager\PayloadManager_user.pdf*

SRC Polygon ground base

SRC Polygon base is a test complex for improvement of a various class rockets.

SRC Polygon location:	101.097 deg E, 1.274 deg N (Sumatra Island, Indonesia)	
VOR transmitter:	ID = SRCL, Freq = 132.0	
VTOL support:	Pad 1 ILS 129.10 Pad 2 ILS 129.20 Pad 3 ILS 129.30 Pad 4 ILS 130.10	
Runways	08/26 ILS 115.10/115.20	lenght 5000 m

The top view on SRC Polygon base is resulted below:

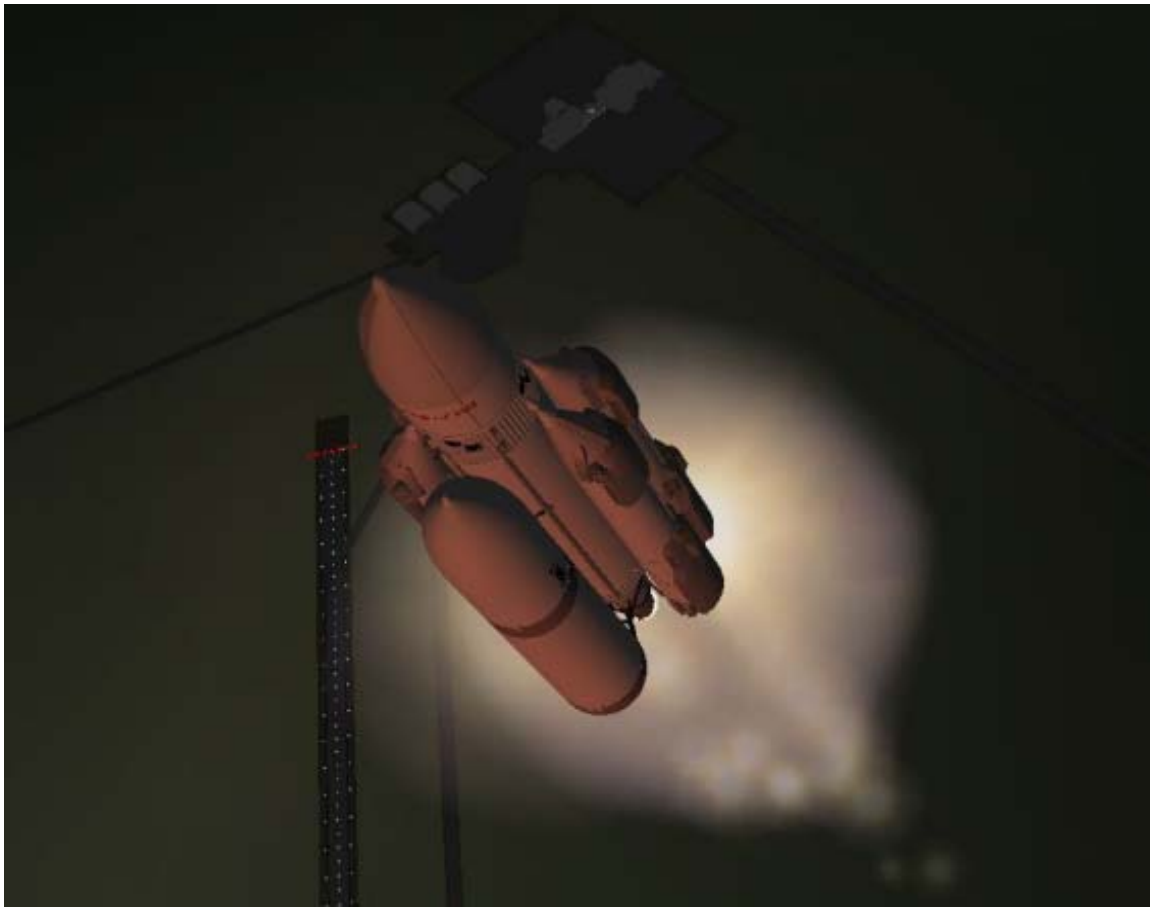


Legend:

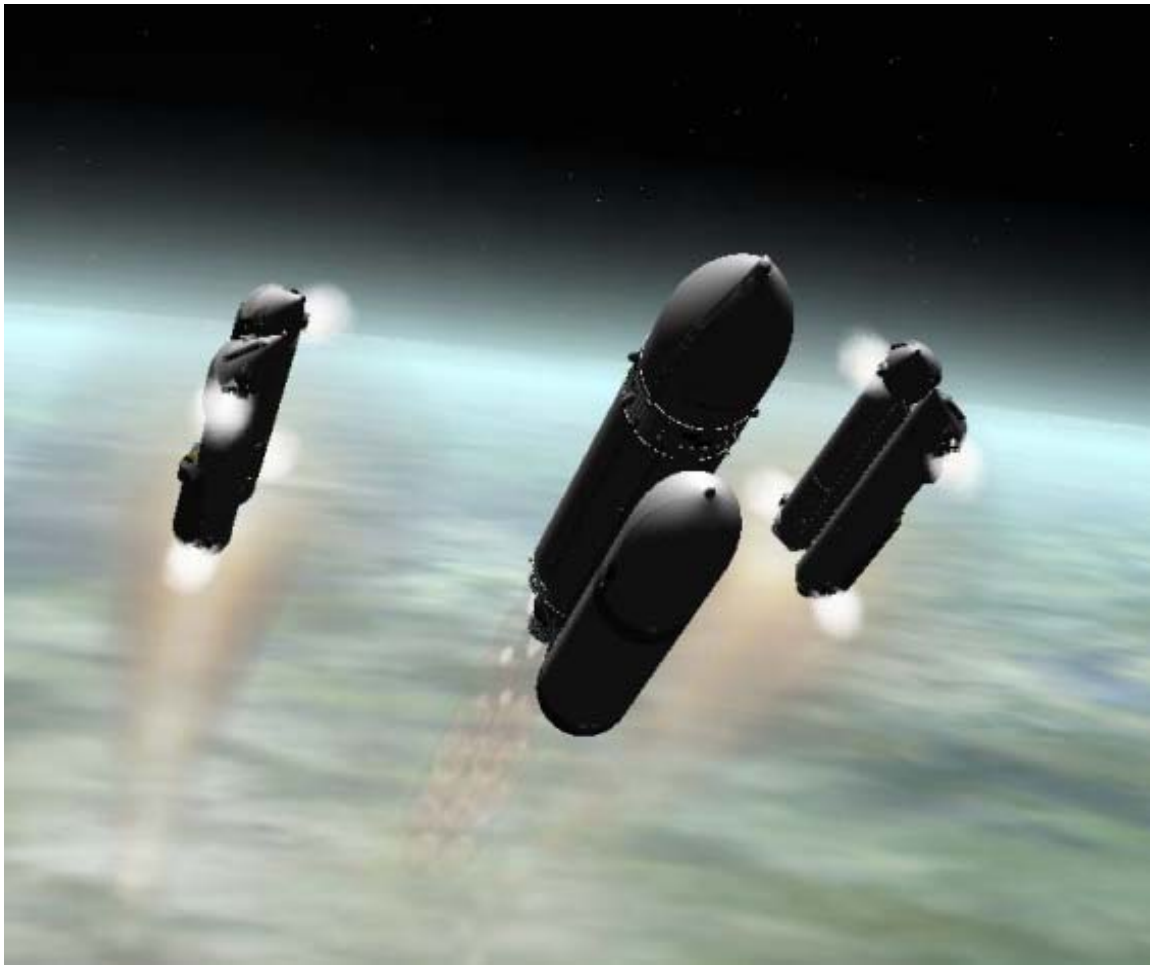
1 Mission control buildings and radar station
2 Fuel factory
3 Technical position (hangars etc.) and VTOL pads
4 Solar plant
5 HLLV assembly buildings and technical position
6 First HLLV launch site (Energia, Energia-2, Vulcan)
7 Way to the perspective launch sites (NOVA, etc.)
8 Residential zone and railway station
9 Railway to the SRC Space Port
10 Railway to the Star City
11 Runway length 5000 m

Screenshots

A Night Launch

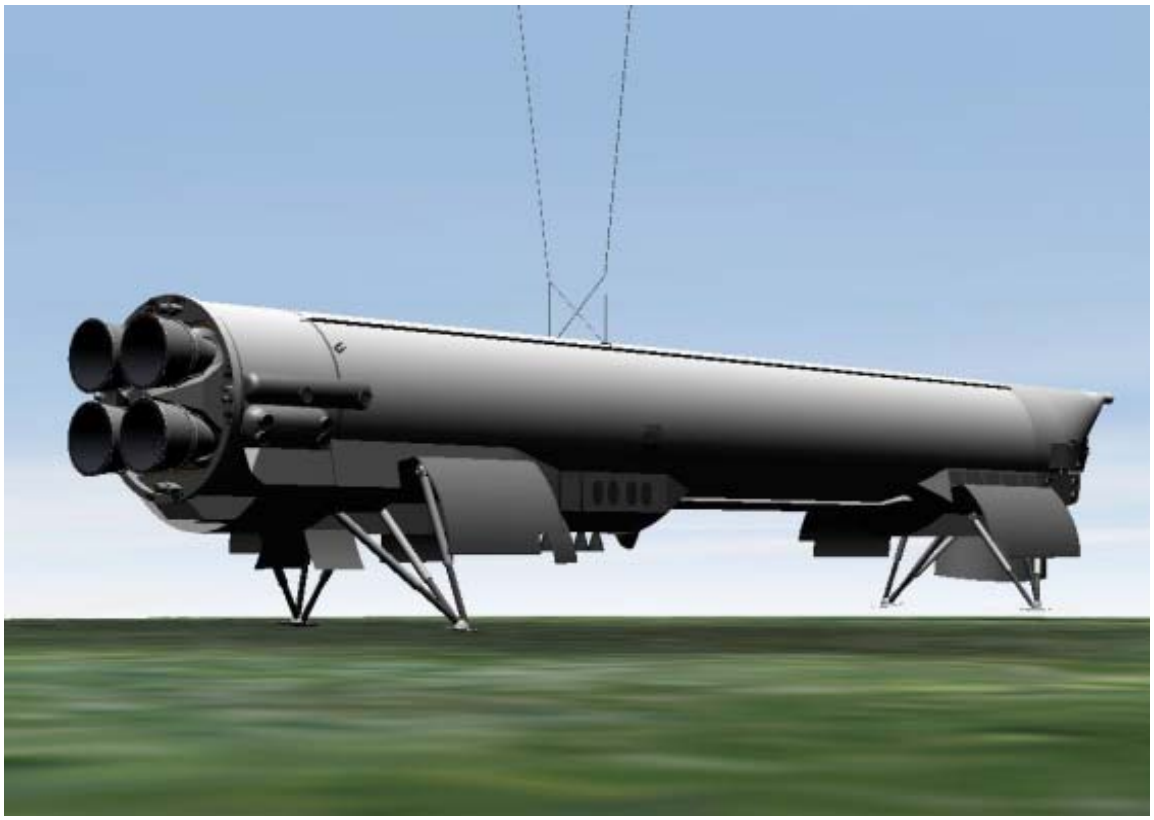


Start from SRC Polygon with Buran-T



First stage separation

First stage descending



First stage landing system

At the Start With Buran (by Jkanios)

Another Buran (by Mark Petroff)


Three Energias at launch position