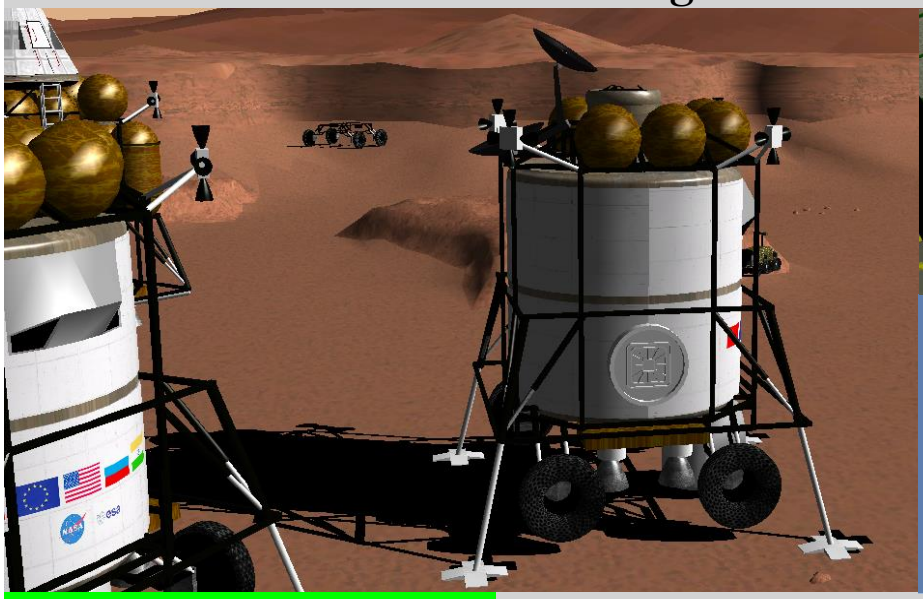
Mars Design Reference Mission 1 [v1.5]



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Mark Paton

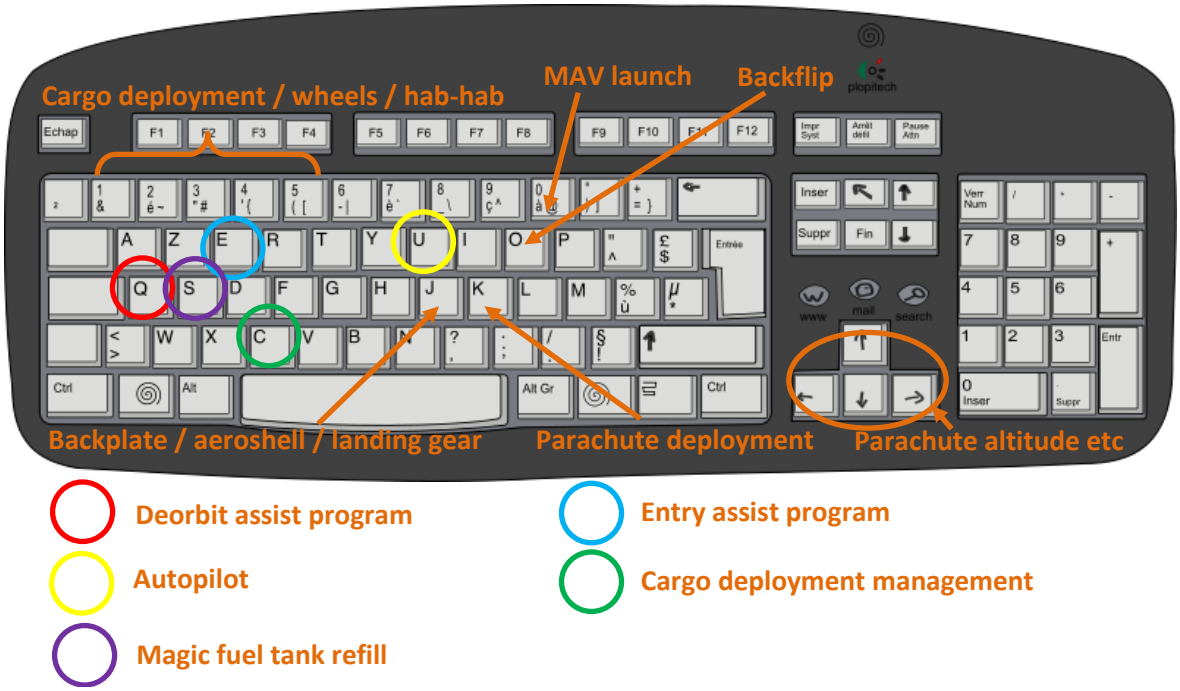
Contents

1. Quick Guide

This add-on aims to test the NASA Design Reference Mission 1.0 in a virtual environment, i.e. Orbiter. In addition it uses the DRM hardware to test the feasibility of manned exploration of the Solar System. Installation: Unzip into Orbiter directory. The version includes its own modules, built in flight computers and autopilots. No further add-ons are required for the main scenarios. Basically you can land from orbit by first **pressing "q"** and then **pressing "u"**. This will bring you to a soft touchdown somewhere on Mars. To land where you want on the surface however might requires a bit more work from the pilot.

Lander keys:
o – perform aeroshell back-flip
k – deploy parachutes
j – jettison connector, backplate, aeroshell, deploy legs, cargowheels
u – activate deorbit burn, entry, descent and landing autopilot
e – display entry flight computer info on HUD
q – display deorbit flight computer info on HUD
w – toggle function of arrow keys – HUD text / CoM / etc
s – magic fuel tank refill
p – open airlock
b – info on UMmu crew
m – add crew
c – grapple cargo (shift-c to release)
1 – null downrange (approach) / descent velocity (powered descent)
2 – null crossrange with bank / null translation velocity
3 – null crossrange with rcs / heading to target
4 – add wind to parachutes / fly "glide path" to landing point
6 – deploy pressurized rover, deploy habitat wheels
7 – crew EVA
8 – select crew / info on cargo
9 – select crew / select cargo from disk (shift-9 add cargo)
0 – Launch MAV (press twice), extend habitat passage
arrow keys – various parameters
Tele-rover keys:
1 – decrease sounding rocket launch angle
2 – increase sounding rocket launch angle
3 – launch sounding rocket
4 – 20 second launch countdown
5 – load new rocket
Sounding rocket keys:
1 – toggle on and off the weather data
2 – add wind data
Earth Return Vehicle:
1 – deploy/retract solar panel
j – jettison backplate and aeroshell
Heavy Lift Launch Vehicle:
0 - add payload
1 - release payload
2 - start countdown
Shift+q - increase parking orbit altitude
Shift+w - decrease parking orbit altitude

Some of the most important keys:



Things to note:

1. For the deorbit and entry autopilots to do their jobs well requires that the adjustment of the orbit inclination so it passes over the target landing location and the orbit is roughly circular with an altitude greater than 120 km.

2. Deorbit burn, entry, descent and landing are fully automatic. The autopilot has to be activated by **pressing "u"**. Different autopilots programs are available for guidance and control of the lander to the target landing site.

3. You can expect to parachute in directly on top of your target coordinates! The guidance, navigation and control programs are pretty sophisticated. The closest I have achieved lander release over the target has been less than 100 metres.

4. The arrow keys can be used to change the coordinates of the text on the HUD, change the parachute deployment altitude, shift the centre of mass, descent velocity and some other things. Each item that you want to change using the arrow keys has to be selected by repeated presses of "w". The options will appear in the upper left hand corner of the HUD.

5. UMmu messages are shared with messages on the HUD from this add-on and may overlap. You have to wait 15 seconds then the UMmu message will clear.

2. UMmu and UCGO compatibility status and keys

I have made this add-on compatible with Dan Steph's UMmu and UCGO add-on which allows users to exchange crew and cargo between ships in Orbiter that are UMmu / UCGO compatible. The UCGO / Ummu add-on has to be installed in your Orbiter folder. The UMmu / UCGO addon can be found by following the link below:
UMmu / UCGO URL : : http://orbiter.dansteph.com

The following UMmu functions are available with the DRM 1 ships:

- Transfer of crew between docked ships (habitat lander, cargo lander and Mars Ascent Vehicle)
- EVA from 3 "ships" (habitat and cargo lander, Mars Ascent Vehicle and the pressurized rover)
- Saving crew to and loading crew from scenarios
- Loading of crew members while running a scenario

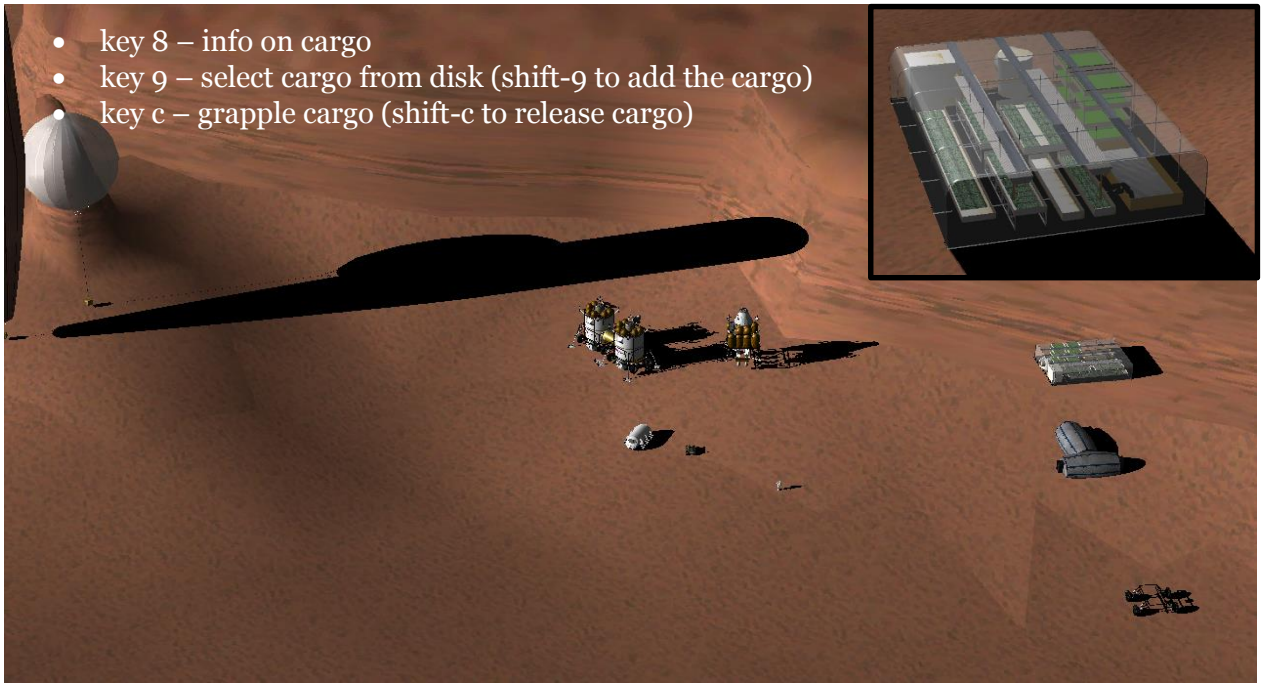
The UMmu keys for all ships are as follows:

- key 7 – perform EVA (i.e. exit the ship)
- key 8 – select crew member
- key 9 – select previous crew member
- key p – toggle airlock door between open and closed
- key b – obtain information about crew
- key m – add a crew

You can have up to 6 crew members in the landers or rover. See UMmu documentation for further details. There is an example scenario with crew members added in the "other addons" folder along with the rest of the scenarios.

If you don't have UMmu installed you can still run the scenarios except a message will pop up at the bottom of the screen (try to ignore it).

The UCGO keys for all ships are as follows:



3. Introduction

The purpose of this technical/experimental Orbiter project was originally to virtually try out the landing system proposed in a NASA early Design Reference Mission (DRM) from the 1990s for landing humans on Mars and to have some fun doing it. Since version v1.4 testing with the new version has shown the landing system works given the propellant and mass budget given in the NASA DRM document. The DRM hardware has been virtually adapted for manned exploration of the Solar System in Orbiter to explore some aspects of long distance exploration.

Deorbit and entry flight routines are built into the landers C++ code to guide the pilot to a precise landing. This system is now quite well developed enabling a landing of the crewed lander next to deployed cargo. It is possible to deploy the parachutes within a few hundred metres of a previous landed vehicle or base. The powdered descent can land the vehicles within a few metres of their target.

The landers are based on the DRMs by NASA which are basically working documents to communicate information to interested parties and are not supposed to be complete solutions to the problem of sending humans to Mars. Further details of these DRMs can be found on the internet. This add-on aims to simulate the DRM 1.0 landers.

DRM 1.0
http://ares.jsc.nasa.gov/HumanExplore/Exploration/EXLibrary/DOCS/EIC044.HTML

DRM 3.0 (with some details of DRM 1.0)
ston.jsc.nasa.gov/collections/TRS/_techrep/SP-6107-ADD.pdf

3.1 DRM 1.0 landers

1. Cargo lander with Mars Ascent Vehicle (MAV), pressurised rover, other cargo (see web links above). The MAV + lander is often referred to just as “MAV” which may be confusing.

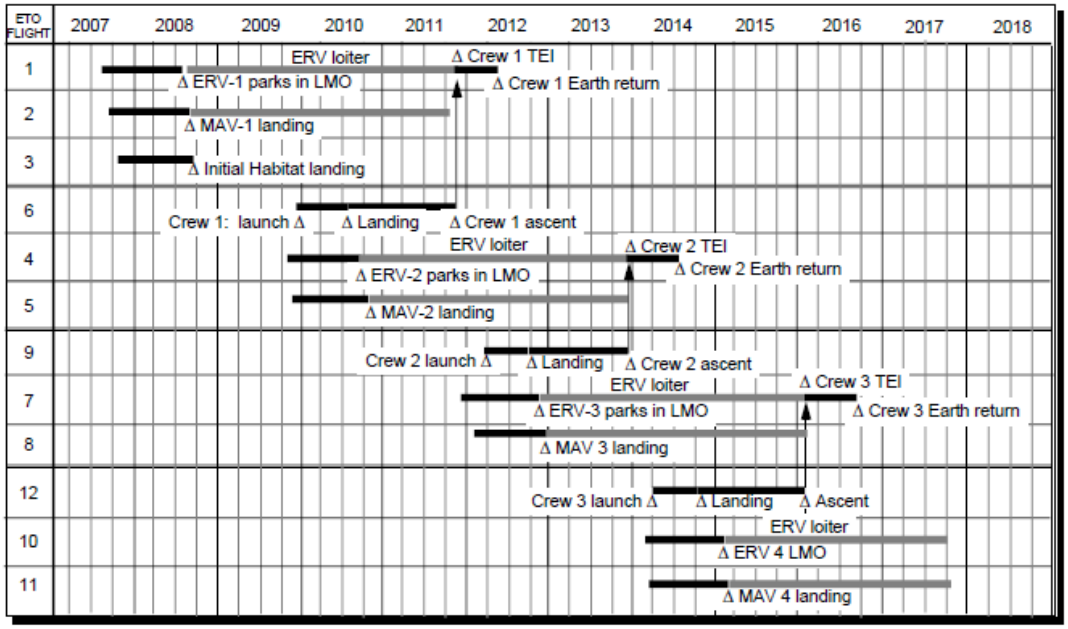
2. Surface habitat 1. Used as a safe haven and to deliver non-perishable consumables. It is referred to as the Mars Surface Lander (MSL).

3. Crewed surface habitat 2. Same as surface habitat 1 except it is crewed.

The landers are delivered in biconic aeroshells to Mars with base diameters of 10 m and a length of 15 m.

Mission summary:

In 2007 the cargo lander and spare surface habitat (landers 1 & 2) are launched and landed on the surface. In 2007 the Earth Return Vehicle (not included in the add-on) is also launched to be put into a parking orbit around Mars. In 2009 the crew is then sent to Mars in the second surface habitat lander (lander 3). After spending 540 days on the surface the crew leave in the Mars Ascent Vehicle (MAV) and rendezvous with the ERV. They then transit Mars to Earth in the ERV habitat and use the MAV capsule to land on Earth.



ERV: Earth Return Vehicle
MAV: Mars Ascent Vehicle
TEI: Trans Earth Injection
LMO: Low Mars Orbit

Diagram from NASA special publication 6107 (DRM 1) page 3-45

Figure 3-7 Mars Reference Mission sequence.

3.2 DRM 3.0 landers (this section is for interest and is not included in the add-on)

1. Cargo lander. This was repackaged to fit inside an aeroshell with a 7.5 m base diameter.

2. Crewed surface habitat. The habitat is integrated with the aeroshell reducing the base diameter of the aeroshell to 7.5 m. Living volume augmented with inflatable habitat. Wheels removed from habitat.

The mass of both landers are reviewed, down from ~90 mT at entry for DRM 1.0 to ~60 mT at entry for DRM 3.0. The backup habitat is scrubbed from the mission. The smaller aeroshell and lower mass mean a less expensive launcher can be used and so bring costs down.

Mission summary:

In 2011 a cargo lander with the MAV (lander 1) are launched to Mars as well as an ERV into orbit around Mars. In 2014 the crew is launched in the surface habitat lander (lander 2) towards Mars.

3.3 Updates for DRM 1 v1.5

A major part of the work for this update was an enhancement of the return to Earth part of the mission. The Earth return capsule mesh and textures are completely new. A virtual cockpit (2D) has been added to the capsule with working buttons and screens. Instead of parachutes the capsule lands using a parafoil allowing a more precise landing. An autopilot uses guidance programs to fly the capsule through entry and descent to a preselected base.

The mesh and textures for the habitat have been updated. The textures are intended to add a more international dimension to the mission that would no doubt be required for Solar System exploration. For both landers the autopilots and guidance programs have been improved.

A major addition to the project has been the implementation of one of the Heavy Lift Launch Vehicle design described in the NASA DRM documentation.

4. Lander mass and landing system numbers

Entry and Descent Systems (same for both landers)

Aeroshell	*: 16000 kg*
Backplate	*: 1000 kg*
Main parachutes	*: 700 kg*

LANDER 1 (cargo lander)

Lander	*: 4670 kg*
Pressurised rover	*: 15500 kg*
MAV	*: 8050 kg*
Cargo	*: variable (0 to 32700)*
Hydrogen feedstock	*: not budgeted in yet*
Lander propellant	*: variable (0 to 150000)*
Total lander mass	*: 72890 kg*
Cargo lander at entry	*: 90890 kg*

LANDER 2 (crewed lander)

Habitat lander	*: 60710 kg*
Propellant	*: 11970 kg*
Total lander mass	*: 72980 kg*
Crew lander at entry	*: 89980 kg*

Other information

Aeroshell

Lift over drag	*: 0.45*
Angle of attack	*: 20^0*
Wing area	*: 210 m^2*
Drag coefficient at 0 AoA	*: 0.4*

Parachutes

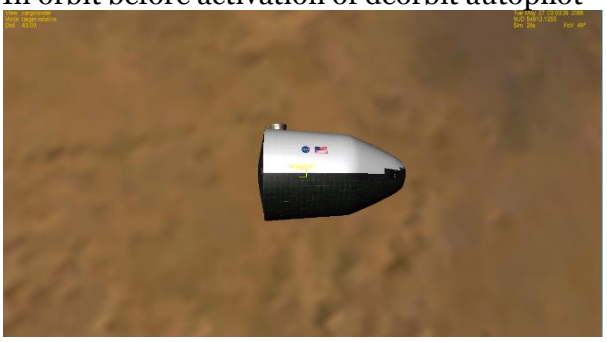
Parachute diameter	*: 50 m*
Drag coefficient	*: 0.45*
Number of main parachutes	*: 4*

Engines

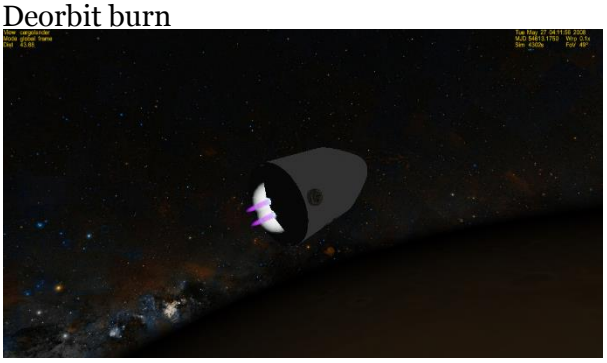
Hover engine thrust	*: 250 kN*
Number of hover engines	*: 4*
Specific impulse	*: 420 s*

5. Landing vehicle operations

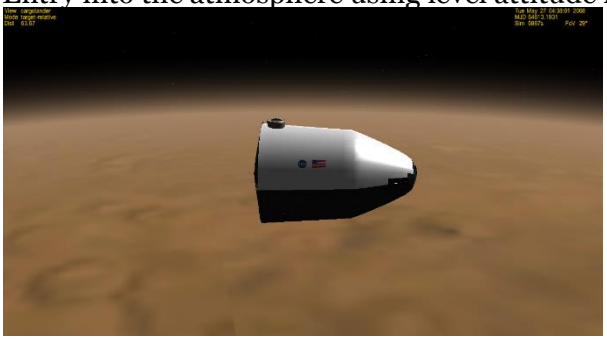
In orbit before activation of deorbit autopilot



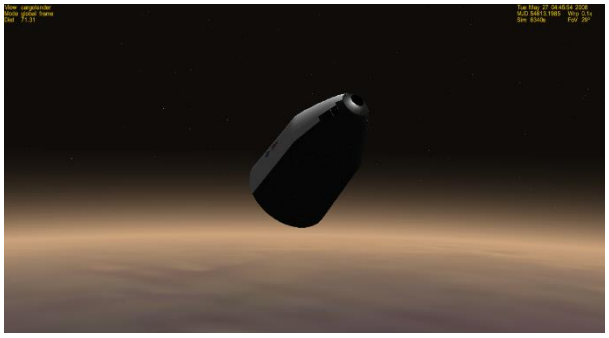
Deorbit burn



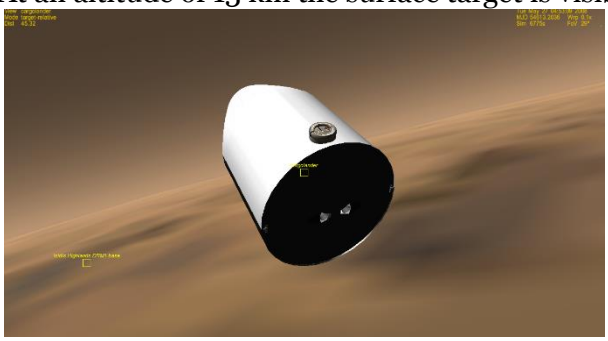
Entry into the atmosphere using level attitude for stability

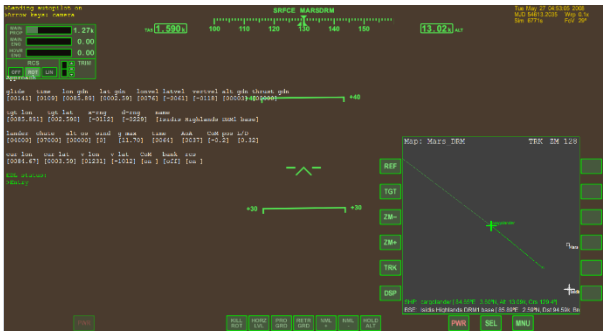


Below 50 km the angle of attack is varied under instruction from the guidance program

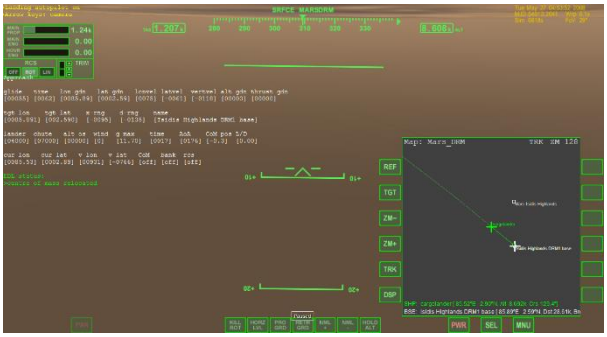


At an altitude of 13 km the surface target is visible

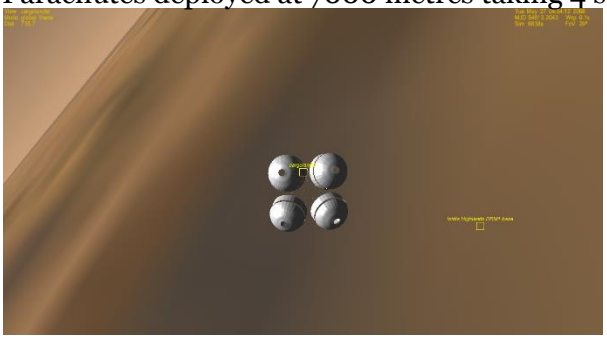




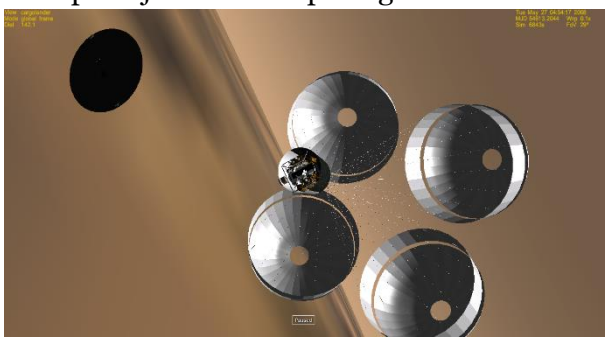
Below 9500 metres altitude the aeroshell rotates ready for parachute deployment



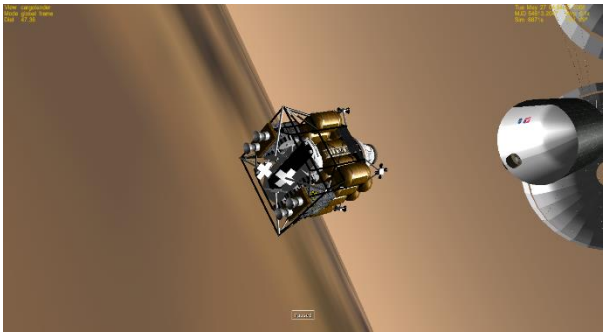
Parachutes deployed at 7000 metres taking 4 seconds to fully deploy

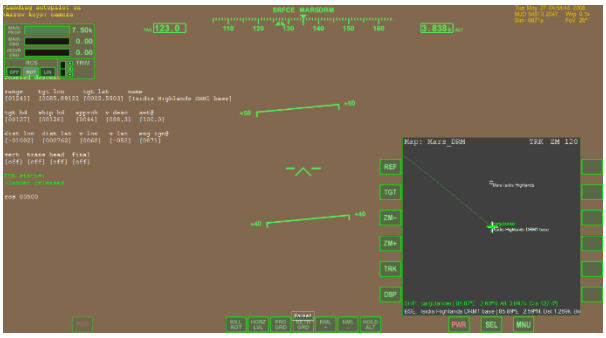


Back plate jettisoned exposing the lander

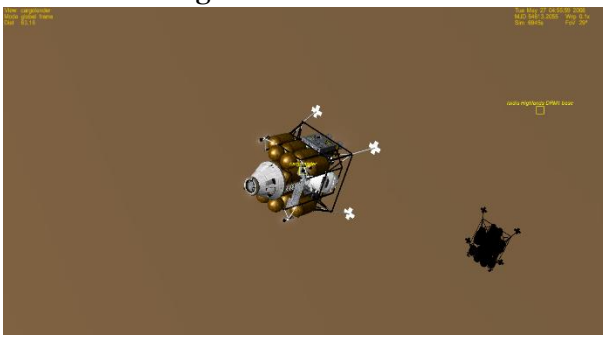


Lander released from the aeroshell





Close to landing on the surface



5.1 Earth Return Capsule (needs updating)

Below shows an image of the panel for operating the capsule. The top screen shows flight navigation data from Orbiter in the top two rows. The 3rd and 4th rows show data from the guidance programs. The bottom row shows vehicle data. The bottom screen shows information that can be changed by the capsule pilot such as the altitude the aerofoil deploys and the angle of attack that is used by the pitch autopilot to control pitch. The switches, top right, are for activating different capsule systems such as pitch and bank autopilots, vehicle guidance programs, deployment of landing gear and aerofoil. Currently switches 3 & 11 are not working.

Instructions for landing at Cape Canaveral

a) After starting the scenario ”Cape Canaveral” in the folder ”DRM1 v1.5 capsule testing” press F8 to display the panel

b) Press down arrow until panel is in full view

c) Switch on the flight computer by press the square button in the middle of the arrows that are just to the right of the bottom screen

d) Set the target for the computer to Cape Canaveral by (a) pressing the up arrow on the panel to change "base" to "vessel" (b) press the right arrow on the panel to jump across to set the target (c) press the up arrow until "Cape Canaveral" is shown

e) Set the AoA (Angle of Attack), for the pitch autopilot, to 140 deg by pressing the left or right arrow until the "=" sign is next to the AoA label (b) press the down arrow until 140 is shown

f) At about 80 km altitude activate the pitch autopilot by pressing switch 4

g) Then activate the guidance for the capsule by press switch 8

h) Then activate the bank autopilot by pressing switch 1

i) At about 15 km altitude activate the aerofoil master autopilot by pressing switch 13.

j) Then switch of the capsule autopilots (switches 1, 4 and 8)

k) Sit back and hopefully land

Note on capsule configuration from scenario file:

The number after AEROFOIL is used to configure the capsule, so AIROFOIL 1 is the capsule, AEROFOIL 2 will start the scenario with the aerofoil deployed.

```
BEGIN_SHIPS
DRM1_capsule_1-5:DRM1_MAV_1-5
  STATUS Orbiting Earth
  RPOS 6040046.40 1671759.46 -1608244.32
  RVEL 1176.326 2074.110 7545.871
  AROT -173.76 -42.67 -77.09
  PRPLEVEL 0:0.996816
  AEROFOIL 1
END
END_SHIPS
```

6. Configuration of the vehicles using the Orbiter scenario files (needs updating)

It is possible to configure the landers in the DRM1 scenarios by changing the numbers that follow the word CONFIG in set-up for the scenario. The line with CONFIG is read when Orbiter starts up and is used by the add-on so it knows which state it is in when a scenario is saved.

The four numbers represent configuration states of the cargo lander. These represent various configurations of the lander. Below is a list of what they refer too and what the values represent.

1. Fuel tank level : empty (0) or full (1)
2. Pressurised rover : deployed (0) or stowed (1)
3. Mars Ascent Vehicle : launched (0) or stowed (1)
4. Aeroshell : released (0) attached (1) connector (2)

So if the first number is set to zero, i.e. CONFIG 0 1 1 1, then the cargo lander will not have any fuel on board. If the first number is set to 1 then the fuel will be add so the total mass of the lander equals the same as the habitat lander which is 92890 kg. The amount of fuel added depends on the amount of cargo added. So if no cargo is on board the maximum amount of fuel that can be added is 47200 kg. If a full load of cargo is on board (32700 kg) then the maximum amount of fuel that can be added is 15000 kg.

If the 4th number is set to zero, i.e. CARGO 1 1 1 0, then the aeroshell and backplate will be missing. If the 4th number is set to 1, i.e. 1 1 1 1, then the aeroshell and the backplate will be present. If the 4th number is set to 2, i.e. 1 1 1 2, the aeroshell will be present with a connecting ring that connects the aeroshell to Wishbone's NTR stage.

Below is some text from a scenario showing examples of the landers in different states. The full scenario can be found in the "extras" folder along with the DRM1 scenarios and is named, "04. Examples of lander configurations".

```
BEGIN_SHIPS
cargolander1:DRM1_cargo
  STATUS Landed Mars
  POS -128.1892067 17.6125798
  HEADING 46.31
  AFCMODE 7
  PRPLEVEL 0:0.949199
  NAVFREQ 0 0
  CARGO 1 0 1 0
END
cargolander2:DRM1_cargo
  STATUS Landed Mars
  POS -128.1882067 17.6125798
  HEADING 46.31
  AFCMODE 7
  PRPLEVEL 0:0.949199
  NAVFREQ 0 0
  CARGO 1 0 1 0
END
cargolander3:DRM1_cargo
  STATUS Landed Mars
  POS -128.1872067 17.6125798
  HEADING 46.31
  AFCMODE 7
  PRPLEVEL 0:0.949199
  NAVFREQ 0 0
  CARGO 1 1 1 0
END
END_SHIPS
```

In a similar way the habitat lander can be configured for the deployment of its wheels and connecting passageways. The wheels can be deployed by setting the first value to zero e.g. CARGO 0 1 0. The passageway can be deployed by setting the second value to zero e.g. CARGO 1 0 0.

Heavy lift launch vehicle

Keys:

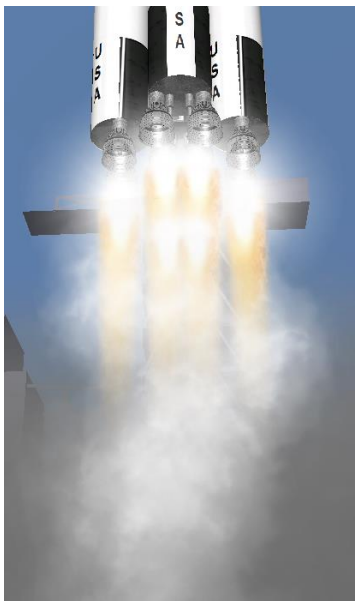
"0"x1 –	add payload to launcher
"0"x2 –	move payload to a crew or cargo loading area
"0"x3 –	move payload back to launcher
"3" to "8"	moves the payload
"1" –	detach payload
"2" –	start countdown and autopilot

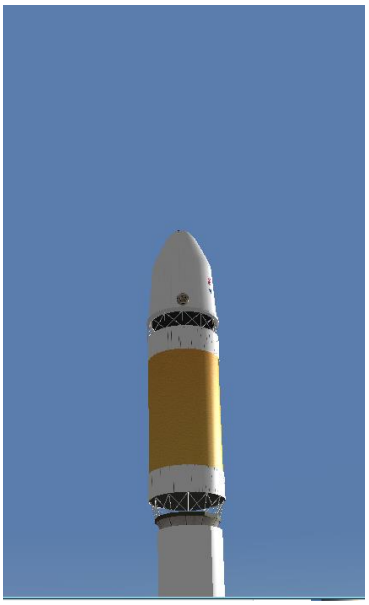
"Shift+Q" - increase final orbit altitude
"Shift+A" - decrease final orbit altitude
The final orbit altitude is shown on the HUD

Various features of the launcher can be configured in the scenario file.

```
DRMrocket:DRM1_launcher
  STATUS Landed Earth
  POS -80.5828028 28.5838273
  HEADING 270.00
  AFCMODE 7
  PRPLEVEL 0:1.000000
  NAVFREQ 0 0
  EMBARK -9806.000000 -6871.000000 -120.000000
  LAUNCH 1
  FAIRING 0
  XYZ 0 0 -20
  ROT 0 0 0
  DIR 0 0 0
  TIGHT 1
END
```

EMBARK	these are the coordinates relative to the launcher for loading crew and cargo
LAUNCH 1	automatically starts a 10 second countdown
FAIRING 1	adds the fairing "0" removes the fairing for e.g. oversize payloads
XYZ	these are the coordinates used to adjust the position of the payload
ROT	the rotation of the attachment point
DIR	the direction of the attachment point
TIGHT 0	indicates that payload is attached preserving its orientation





7. Adding Isidis Highlands terrain

To install the terrain requires a little bit of work. Firstly the mesh needs to be obtained from Foxtrot's Isidis Highlands addon on avsim.com. This requires you to login, download the addon and then extract the mesh into the Orbiter mesh file. Secondly the texture needs to be extracted from the Mars landmarks addon by alexander_spb on Orbit Hanger Mods (link at bottom of page) and placed in the Orbiter texture folder. Thirdly the configuration file needs to be updated in the sub-subfolder called "base" in the subfolder Mars in the Orbiter main configuration folder.

The steps are as follows:

1. Extract the mesh file called "isidis-highlands.msh" from the Isidis-Highlands addon and place it in the Orbiter mesh folder

2. Extract the texture file called "isidis-highlands.dds" from the Mars landmarks addon (link at bottom of page) and place it in the Orbiter texture folder

3. Extract the configuration file from the Mars lanmarks addon called Isidis-Highlands.cfg and place it in the Base folder for Mars (Config\Mars\Base)

4. Open the configuration file with notepad or some other text editor. Then change the number -4099 to -4109 so it looks as follows :

```
Base-V2.0
Name = Mars Isidis Highlands
Location = +85.87 +3.3
Size = 5000
Objectsize = 1500

; === List of visuals ===
BEGIN_OBJECTLIST
MESH
  FILE isidis-highlands
  POS 0 -4109 0
  ROT 0
  OWNMATERIAL
END
LPAD1
    POS 42240 0 1300
    SCALE 0 0 0
    TEX Lpad01
END
END_OBJECTLIST
```

Above: terrain with MAV in the foreground.

Save and close the file and you should be ready!

New textures for Martian landmarks:
http://www.orbithangar.com/searchid.php?ID=5493

8. Autopilot programs : a summary

There are a number of tools to help you land on the surface. These include programs to provide deorbit and entry information. There is a deorbit burn, entry, descent and landing autopilot which will take care of the landing. During entry the angle of attack can be changed manually to correct any errors made by the autopilot. Also the parachute deployment altitude can be changed to further correct errors when closer to your target.

7.1 Deorbit flight program

The deorbit assist program feeds into the timing of the autopilot deorbit burn or can be used to help the pilot to perform a manual deorbit burn. The program will calculate the deorbit burn location along a ship's orbit that places the location of entry into the atmosphere so the ship can reach close to the target coordinates just by hypersonic gliding.

There are two conditions that need to be met before the deorbit computer is useable with any degree of accuracy (if these are not it may still be able to land but the ship may not be able to reach the target coordinates).

1. The orbit needs to be approximately circular.

2. The orbit has to be positioned so it passes over the target at any time. As long as you leave at least one orbital period before you intend to land then you'll be A-ok.

The computer is then activated by **pressing "q"** one orbital period before you land i.e. when it passes the latitude of the target. This sets the target location. The program then works by simply tracking the distance you travel along the orbit path and using a previously calculated deorbit location. This is from knowing the hypersonic glide capability of the ship (which is determined with an "on board" simulation of the entry). The deorbit program displays the following information on the HUD screen. Remember to **press "u"** if you want the autopilot to perform the deorbit burn.

burn@ - distance until deorbit burn (km). This is the distance along the (final) orbital path, in the direction of motion, before the deorbit burn takes place.

so far – distance travelled so far (km). This is the distance between the base and the vehicle along the orbital path in the direction of motion. This will be different from the shortest distance between your current location and the target base that is displayed at the bottom of Orbiter's Map MFD.

to go – distance to go until deorbit burn (km). This is a countdown, in distance, until the deorbit burn will be performed.

glide distance – predicted travel distance in atmosphere (km). This is the distance the ship will travel during its hypersonic entry after it passes through the entry window at 120 km altitude.

The angle attack that the deorbit program uses to calculate the glide distance can be changed by toggling the arrow keys function with the **key "w"** and then using the **arrow keys.** The glide distance also takes into account parachute deployment which is set at 10 km altitude.

8.2 Guidance program : approach phase

Information is calculated by the guidance program during entry and displayed on the HUD to help guide the pilot or autopilot to the target location. The program uses Orbiter's model of the planetary atmosphere, e.g. Mars, together with the program's equations of motion to calculate the trajectory

and predict the lander delivery point. The lander delivery point is the altitude, longitude and latitude where upon the powered descent phase is initiated. The autopilot (or pilot) uses the information from the guidance program to adjust the flight path so the predicted delivery point location coincides with the target location.

The entry program output can be displayed on the HUD by **pressing e**. This will provide the following information.

text row 1 : guidance program output
glide the predicted hypersonic glide distance in kilometres
time time to chute deployment
lon gdn longitude in degrees of the delivery point, i.e. 1 km below the parachute deployment point.
lat gdn latitude in degrees of the delivery point.
lon vel delivery point longitudinal velocity
lat vel delivery point latitudinal velocity
vert vel delivery point vertical velocity
alt gdn altitude of the delivery point (1 km below the parachute deployment)
thrust gdn thrust level used by the guidance program/autopilot when landing on airless worlds
text row 2 : target information including downrange and crossrange errors
tgt lon longitude of the target
tgt lat latitude of the target
x-tng the predicted cross-range error for the landing
d-rng the predicted down-range error for the landing
name the name of the target vessel or base
text row 3 : Autopilot settings, max g and aerodynamic properties
lander release altitude of the lander from the aeroshell
chute the altitude of the parachute deployment
alt os target altitude offset
wind "1" indicates winds are effecting the parachute
max g maximum g level during entry
time amount of time in seconds before maximum g level
AoA The angle of attack. Changing this will affect the landing latitude and longitude. It can be changed by using pitch thrusters (if you have any fuel left) or by shifting the centre of mass (CoM).
CoM pos Centre of mass position. This indicates the location of the centre of mass of the ship. Useful for changing the angle of attack when low on fuel.
LoD Lift over drag.
text row 4 : Current location and speed and active autopilots
cur lon current longitude
cur lat current latitude
v lon velocity in the west to east direction
v lat velocity in the north to south direction
CoM Centre of Mass autopilot program. Changes the angle of attack so the predicted downrange is as small as possible.
bank bank control program. Banks the spacecraft to use aerodynamic forces to minimise the crossrange
rcs rocket control system control program. Fires the thrusters to minimise the crossrange. Can use quite a lot of fuel.

Manually reduce target miss by changing the angle of attack of the aeroshell (i.e. use **numpad 2 & 8** keys to pitch up and down or shift the centre of mass using the **arrow keys**, first select the function of the arrow keys by **pressing w**). The **altitude offset** can be changed using the arrow keys. Again **press w** to select the correct arrow key function.

8.3 Powered descent and landing phase

The powered descent and landing autopilot flies the lander to a landing within 200 metres of a preselected target. The target that can be selected can be a base or a vessel. The autopilot operates a set of four programs similar to Orbiter's "navigation tools" like hold level and hold altitude. These are activated at preprogrammed altitudes and cannot be changed by the pilot. However the autopilot can be switched off and the individual programs can be operated individually by the pilot.

This output from this phase can be displayed, like the entry phase by **pressing e**.

range the distance to the target in metres
tgt lon target longitude
tgt lat target latitude
name name of the target vessel or base
tgt hd target heading
ship hd heading of the lander
v desc vertical descent speed (m/s)
set@ the descent speed set by the pilot or autopilot
eng ign@ the altitude when the descent engines are switched on. This number will increase until it reaches the current altitude whereupon the engines will throttle up.
dist lon the distance in the east to west direction from the target (in metres)
dist lat the distance in the south to north direction from the target (in metres)
v lon the velocity in the east-west direction (m/s)
v lat the velocity in the south-north direction (m/s)
vert vertical descent autopilot program
trans null translation velocity autopilot program
head turn lander to face target
final control final approach path

To change the descent speed **press w** to set the arrow keys function. Then press the up arrow and down arrow and the vertical descent program will adjust the descent speed. The target can also be changed by the arrow keys **press w** until either **target (vessel)** or **target (base)** is displayed at the top of the HUD. Then use the up and down **arrow keys** to move through the bases or vessels active in your install of Orbiter.

8.4 Cargo deployment

Cargo deployment is managed by another Orbiter add-on called UCGO. See UCGO documentation for details.

The UCGO cargo can be moved around the surface using a cargo transportation vehicle that consists of the habitat wheels and frame. This can be deployed from a habitat by **pressing J.** The "cargo wheels" can then load and unload standard UCGO cargo.

9. Updates

Heavy Lift Launch Vehicle with payload capability of 269 tons. Can be used with other addons.
Virtual cockpit with buttons added (2D) to the Earth return capsule
Autopilot added to the Earth return capsule
Internal cockpit mesh added to the habitat
Parachute added to the cargo lander
New meshes for habitat and capsule
Earth tracking high gain antenna on habitat lander
Manual operation of landing gear enabled
Added sounds to launcher for booster separations and undocking of NTR
Updated the habitat and cargo lander autopilots to allow descent without the aeroshell
Also the lander (and capsule) autopilots can be used on any planet in Orbiter
Added possibility of changing the lander release altitude from the aeroshell
Cargo lander made UMmu capable
Extra cargo points added on the cargo lander allowing up to 12 cargo boxes to be added

10. Links

Wishbone's NTR core propulsion stage. Under development but essentially working. Keep up to date with developments here: http://www.orbithangar.com/searchid.php?ID=5215
80mileshigh Russian Mars Transfer Vehicle:
http://www.orbithangar.com/searchid.php?ID=4562
Interplanetary MFD
http://orbithangar.com/searchid.php?ID=1844
Aerobrake MFD
http://orbithangar.com/searchid.php?ID=2139

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Daniel Polli : UMmu code

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On the Orbiter Forum : Thanks for all the excellent comments and encouragement from members of the Orbiter forum that helped improve this addon. http://orbiter-forum.com/showthread.php?t=21972
