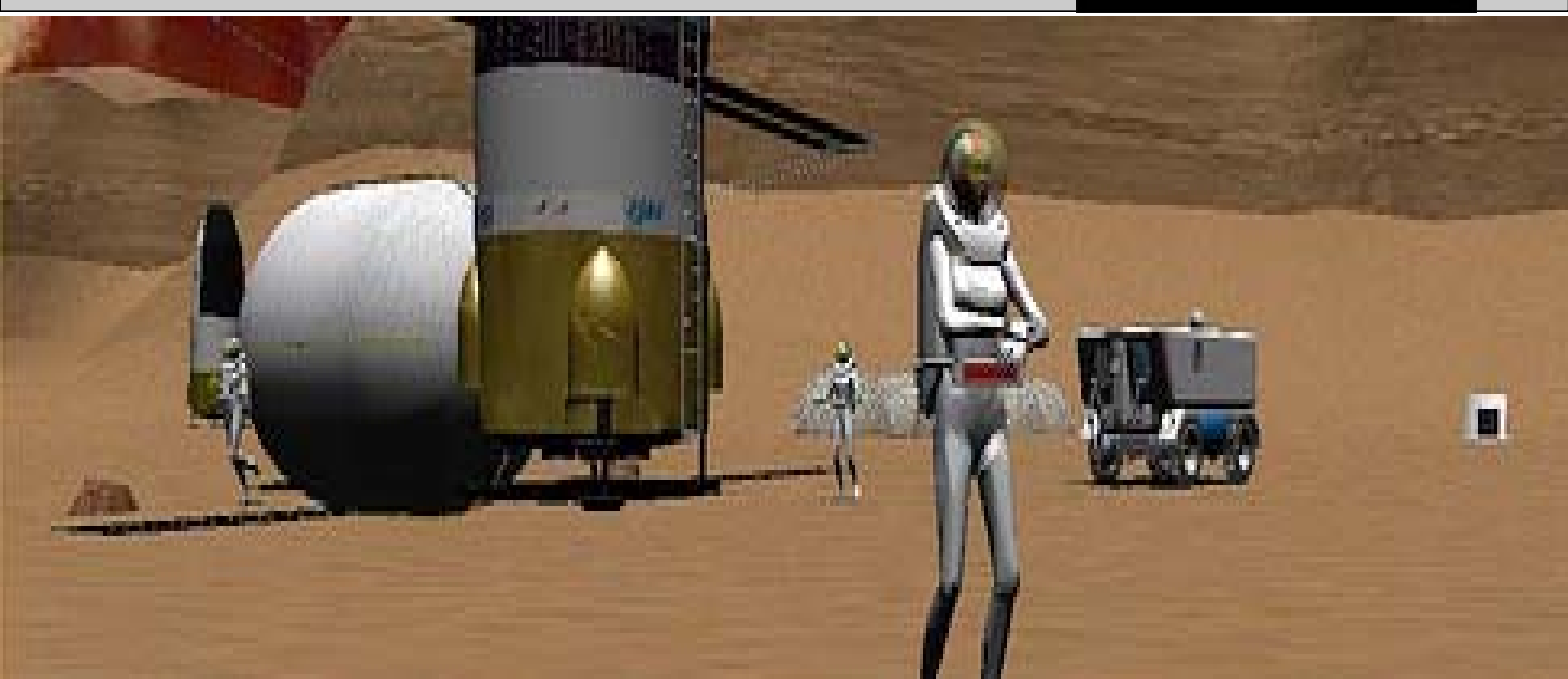
Mars for Less
Add-on Package for Orbiter
February 2008

by

Andy McSorley,

Mark Paton,

and Bruce Irving



Contents

1. Installation

Disclaimer

The authors of this add-on can take no responsibility for any damage caused to your computer by installing and using this add-on. Nor can they take responsibility for hair loss, sleepless nights and broken marriages that may result from spending too many hours playing with it!

We don't THINK there are any conflicts with other add-ons (or installation order dependencies), but we don't know for sure.

Assumes

To get the best from this add-on you will need to have a good knowledge of Orbiter as well as an understanding of IMFD 4.2.1. For a good tutorial on how to use this earlier version of IMFD, one can be found in the eBook by Bruce Irving and Andy McSorley that is freely available to download from -
http://www.aovi93.dsl.pipex.com/play_in_space.htm

Instructions for installation

For best results install the required files into a new Orbiter installation. This distribution contains all the necessary spacecraft dlls and Multistage 2 dll by Vinka. Always preserve directory structure ("use folders") when unzipping add-on files to your Orbiter installation directory.

Table 1 shows the full list of files used for the Mars for Less Virtual Prototyping project in a recommended installation order. The first and most important is the simulator itself, Orbiter. This is available free for download from orbitersim.com or http://download.orbit.m6.net/mirror.html.
The next add-on, which gives the simulator sound effects and is used by many people as an essential part of the simulation experience, is Orbiter Sound. This is available from http://orbiter.dansteph.com/index.php?disp=d.
The next installation package is this one, the Mars for Less package. The MFL package also includes a zip file NASA_VSE_SC_v2.0dev_MFL20060614 - Simcosmos's Crew Launch Vehicle - included in the package as a seperate zip file. During installation, and when prompted, say 'Yes to all'.

The following add-ons should also be unzipped (See table for links). KourouCSGv3 - Say 'Yes to all' when prompted. CEV-E-02 (Francis Drakes CEV), Vallis Dao - by jtiberius, IMFD 4.2.1 - by Jarmo, Auto Pilot 1.7 - by Medec21 - Say NO when requested to overwrite existing Earth CFG. This saves on scenario load time. Don't forget to activate IMFD and Autopilot 1.7 in the Orbiter Launch Pad Modules section.

Table 1 Add-ons required to run MFL simulations. Installation order shown in left hand column. First four are the most essential ones.

	Add-on name (description)	**File**	**Size (MB)**	**Date uploaded (DDMMYY)**	**Internet link**
1	**Orbiter 2006 P1**	***Orbiter060929_base.zip***	**63.0**	**290906**	**http://download.orbit.m6.net/mirror.html**
2	Orbiter Sound 3.5	*OrbiterSound35.exe*	11.5	------	http://orbiter.dansteph.com/index.php?disp=d
3	Mars for Less	***MFL_V1.6.zip***	24.6	150206	http://www.orbithangar.com/
4	NASA VSE SC v2 (Solid Rocket Booster launcher for the CEV)	***NASA_VSE_SC_v2.Odev_MFL20060614.zip***	5.1	------	**SPECIAL NOTE:** Included zip file in – MFL_V1.6.zip above.
5	Kourou – Guyana Space Centre	*Kourou-CSG_v3.zip*	12.4	200806	http://orbiter.mustard-fr.com/addons/kourou.php
6	ESAS CEV (Exploration Systems Architecture Study Crew Exploration Vehicle)	***CEV-E-02.zip***	1.6	311205	http://orbithangar.com/searchid.php?ID=1972
7	Vallis Dao (Valley on Mars)	***VallisDao2006.zip***	2.0	200806	http://www.orbithangar.com/searchid.php?ID=1359
8	Interplanetary MFD*	*IMFD421.zip*	1.3	------	http://koti.mbnet.fi/jarmonik/Orbiter.html
9	Autopilot 1.7**	*Autopilot17.zip*	8.2	031105	http://www.orbithangar.com/searchid.php?ID=1468
10	TetherMFD***	*TetherMFD-0.96-release.zip*	0.8	160804	http://www.orbithangar.com/searchid.php?ID=439
11	Lunar Rover v4	*K-Lunar-Rover-v4.zip*	0.8	300507	http://www.orbithangar.com/searchid.php?ID=2951
12	Mars Ares Mission (Aircraft for Mars)	*K-Mars-Ares.zip*	1.6	041006	http://www.orbithangar.com/searchid.php?ID=2581
13	LLRV Ver 2 (Lunar Lander Research Vehicle)	*LLRV-V2.zip*	1.6	190104	http://www.orbithangar.com/searchid.php?ID=250
14	Inflatable (Inflatable module for habitation)	*Inflatable.zip*	1.0	160206	http://orbiter.mustard-fr.com/addons

* Don't forget to activate in the Orbiter Launch Pad Modules section. This is not the latest IMFD version but works with 2006 and was used for testing.
** Don't forget to activate and say NO when requested to overwrite existing Earth CFG. This saves on scenario load time (you can also delete the 10,000 airport .cfg files in /AIRAC folder).
*** This isn't used in any of the scenarios but was used during prototyping of MFL

2. MFL Background

The *Mars for Less* (MFL) Reference Mission, developed by Grant Bonin, is basically Robert Zubrin's *Mars Direct* architecture, but divided into smaller components that can be launched using today's medium lift launchers (MLLV, ~25 metric tonne payload) from a number of nations. For this project, Thomas Ruth's freely available Ariane 5 launcher model for Orbiter by was used and modified for the purpose of launching the various spacecraft elements to LEO for assembly. The MFL spacecraft themselves, as well as a special modular upper stage, were developed specifically for this project (based on Vinka's spacecraft3.dll), and a number of other add-ons were also used to simulate various aspects of the MFL mission.

We won't go into the full details of the mission (there are several references you can read for more details, see below), but here is a basic summary of the problem and the MFL approach to the solution.

A human Mars mission requires a lot of mass to be placed into LEO in order to get a reasonable mass to the surface of Mars. Zubrin's key insight in *Mars Direct* was to break the mission into two main parts, and to reduce the delivered mass by first sending an unmanned and non-fueled Earth return vehicle (ERV) to Mars, where it would use robotic ISRU methods to process CO_2 from the Mars atmosphere to create methane (rocket fuel) and oxygen (oxidizer) for the return flight. The crew would follow about two years later. This reduces the total mass for the mission, but still requires at least two heavy-lift launch vehicles (HLLV, 100+ mt payload). NASA plans to develop a new HLLV to support its Moon and (eventual) Mars plans, but until the HLLV is available, no *Mars Direct* or similar Mars mission can be launched.

MFL takes the same basic approach as *Mars Direct*, but proposes that the mission components be divided into ~25 mt modules that are designed for simplified (partially automated) LEO assembly, with six such launches required to assemble the ERV and its four trans-Mars injection (TMI) booster stages. Six more launches would be required for the crew-carrying MTSV. By using identical booster modules, designed for automated LEO assembly and small enough to launch on several different MLLV's from various nations, economies of production could be achieved, and the ability to stage the mission would not be dependent on a single launch vehicle such as NASA's planned HLLV.

Bonin's paper goes into issues such as the required timing of the multiple launches, cryogenic propellant losses in orbit while waiting for assembly (boil-off), launch failure issues, etc. These are not considered in the Orbiter simulation.

The dates of such a mission are of course unknown, but because a major point of using current MLLV's is to make the mission possible both sooner and cheaper, we assumed dates with favorable Mars transfer properties in the 2018-2019 time frame.

References for Background

1. Bonin, Reaching Mars For Less Human Mars Expeditions with Existing Launch Vehicles, Proc. of the 25th International Space Development Conference, Los Angeles, CA, May 4-7, 2006, also see http://en.wikipedia.org/wiki/Mars_for_Less

2. Irving, McSorley, Paton, Bonin – Virtual prototyping of human Mars missions with the Orbiter space flight simulator, Mars Society Conference, August 2006, pdf available from http://orbit.medphys.ucl.ac.uk/manual.html (bottom of the page)

3. Zubrin, Baker, Gwynne, Mars Direct: A Simple, Robust and Cost Effective Architecture for the Space Exploration Initiative, AIAA, 91-0326, 29th Aerospace Sciences Conference, Reno NV, January 1991

3. What Is Simulated and Included?

MFL for Orbiter is divided into several zipped installation files and includes some add-ons developed by others and used with permission. The basic components are designed to simulate the key phases of the mission, including launch to LEO of the crew and propulsion modules, rendezvous and docking of the components to simulate assembly, "pulsed" TMI (i.e., each of the four propulsion modules fires at the right place and time to establish the Mars injection trajectory), guidance/cruise for Mars (IMFD recommended), aerobraking entry into a Mars parking orbit, and Mars EDL (entry/descent/landing) of the MTSV (AutoPilot1.7 required for automated landing). Other aspects of the mission (e.g., MTSV rotation for artificial gravity) can be simulated with the help of additional add-ons developed by others and described in the next section.

1. **ERV** (Mark Paton) – Biconic Earth Return Vehicle, multi-stage vehicle with animated antennas, legs, aeroshield, etc. Launched in two sections that are assembled in LEO, probably with astronaut EVA assistance. Based on Vinka's spacecraft3.dll (included).

   Animation keys for ERV:

   Left-shift numpad 1: Deploy top high gain antenna
   Left-shift numpad 2: Deploy bottom high gain antenna
   Left-shift numpad 3: Expose docking hatch
   Left-shift numpad 4: Deploy solar panels

2. **MTSV** (Mark Paton) – Cylinder-shaped “hab” module (Mars transfer and surface vehicle) with animated antennas, legs, aeroshield, parachutes, etc., designed to carry the crew to Mars, land, and support them there for an extended period. Launched in two sections that are assembled in LEO, probably with astronaut EVA assistance. Based on Vinka’s spacecraft3.dll (included).

   Animation keys for MTSV EDL (mfl_mtsvedl in Orbiter) version featured in scenarios MTSV stack to Mars, Landing practice and Atmospheric entry:

   Left-shift numpad 1: Deploy ladder to the surface
   Left-shift numpad 2: Deploy high gain antenna 1
   Left-shift numpad 3: Deploy high gain antenna 2
   Left-shift numpad 4: Deploy solar panels
   Left-shift numpad 5: Rotate solar panels
   Left-shift numpad 6: Deploy tether attachment device
   Normal keyboard G: Deploy landing legs

   Animation key for the heat shield (mfl_mtsvshieldedl in Orbiter) and parachutes is G. All elements (shield, MTSV and chutes) are attached together using the docking facility in Orbiter and can be separated using CTRL D.

3. **Ariane-5 Launch Vehicle** (Thomas Ruth, modified by Andy McSorley) – This MLLV was used because it is a great model and was available for modifications. It would be one of several MLLV’s that could be used for MFL launches, but only the Ariane-5 was used in this prototype. Two A5 launches would be needed for each Mars crew vehicle (ERV and MTSV, 4 launches total), though it is likely that an additional cargo mission would be used to pre-place supplies and perhaps provide some backup facilities (and to also test the mission hardware). Based on Vinka’s spacecraft3.dll and multistage2.dll (included).

4. **Proteus modular TMI stage** (Andy McSorley) – This is an original design for an H2/LOX stage designed for automated docking/robotic assembly in LEO. Each modular stage has solar panels, maneuvering thrusters, and guidance systems to allow standalone operation and automated rendezvous and remotely operated docking/assembly. Four of these would be launched over a several week to several month period. Based on Vinka’s spacecraft3.dll and multistage2.dll (included).

   Animation key: deploy solar panels using K.

4. Other add-ons

The basic MFL mission phases can be considered to be launch of the various components (assumed for the add-on to all use the Ariane-5 and to launch from ESA's Kourou Space Center), rendezvous/dock to simulate assembly of the components, launch/rendezvous/dock of a simulated crew vehicle (CEV/CLV assumed for the add-on), TMI burns by the four Proteus stages at successive perigees for required Mars trajectory (planned with IMFD), aerobraking into Mars orbit, and Mars EDL. Later basic phases would include launch of the ERV for return to Earth, guidance for the TEI burn and any needed corrections, and finally Earth aerobraking. Additional (optional) phases or features include simulation of tether-based rotation to generate artificial gravity (Tether MFD) and the establishment of a Mars base (using Valles Dao for basic 3D terrain with additional objects added such as a Mars rover, greenhouses, antennas, etc.).

1. Crew vehicle – At least one crew launch would be required to ferry the crew to the assembled MTSV, but other crewed launches would be needed to assist in assembling the ERV and MTSV in LEO and probably also for final fitting and testing of the complete Mars-bound ERV (the Mars crew itself might do the final fitting and checkout of the MTSV prior to Mars departure). Any available crew vehicle might serve this purpose in real life (Soyuz, SpaceX Dragonfly, NASA CEV), but we assumed the NASA CEV (by Francisdrake) and CLV (Ares I) and made use of a model customized for us by Antonio Maia.

2. Flight planning and guidance – We used Jarmonik's IMFD 4.2.1 to help plan and execute the Mars trajectory, "pulsed" TMI, course corrections, and Mars approach.

3. Artificial gravity – During testing, we used the Tether MFD to set up some scenarios with the MTSV rotating with the final spent Proteus propulsion module, mainly for visualization of the spinning concept. Scenarios for this are not included.

5. Brief Scenario and Landing Notes

Scenarios for all mission segments can be found in the Orbiter launchpad with basic instructions and descriptions.

1. ERV Depart for Mars
2. Launch MTSV
3. Mars Entry, Descent and Landing
4. Depart from Mars to Earth
5. Return to Earth Stages
6. CEV
7. Mandya Arti

Further explanation of many scenarios may be viewed in their header descriptions in the Orbiter Launchpad.

There is only one scenario for the ERV Earth Return Vehicle (7.0 ERV Stack to Mars) this scenario has a fully fuelled ERV stack in LEO ready to make the first of four perigee burns using IMFD. After the jettison of each departure stage (Proteus) IMFD has to be set up again for the next burn. The same goes for the MTSV earth departure burns.

The Earth Return Scenario, (Folder - 5.0 Return to Earth Stages) has a fully fueled ERV awaiting launch from the Martian surface (Scenario - 1.0 ERV launch from Valles Dao). This is configured to use multistage .dll, so just press 'P' to launch. The guidance file will only take you partially to orbit, i.e. first stage separation. IMFD is set up with 30 seconds to go until launch.

Some of the MTSV launches are simulated (Folder - 2.0 Launch & Assemble the MTSV Stack) with the guidance file taking each launch as far as main core separation. Launch when the Map MFD indicates the target is within 2-3 degrees of the launch vehicle position. After core separation use the Ariane upper stage to rendezvous with the previously launched elements, using Align, Sync and Docking MFDs. Don't jettison the Proteus payloads until almost docked to the previously launched element, as otherwise control will be very difficult. The Ariane upper stage can be kept attached while awaiting the next launch as a means of station keeping. As a bonus there is also one scenario that has the Ariane 5 configured to use a larger fairing (this might allow use of a wider hab for greater living volume, though this was not simulated).

During the coast phase from Earth to Mars, for practical purposes in Orbiter, it was found that the final Proteus departure stage needed to be retained to make a couple of correction burns. This goes against the option of using it as a counter-weight on the end of a tether to simulate artificial gravity for the crew.

Folder - 3.0 Depart Earth for Mars, contains a series of scenarios all the way from LEO to Martian Orbit, The orbit achieved may not be a suitable one for making a landing a Valles Dao. That part is simulated by the scenarios in folder '4.0 Entry, Descent and Landing at Mars'. How to land is described below by Mark Paton.

MTSV landing practice
****

Mark Paton 12.10.06

The scenario starts with the MTSV travelling at about 1500 m/s. You will need autopilot 1.7 to help you land the MTSV. This is available from Orbit Hanger Mods. The small or drogue chute will deploy automatically at 1150 m/s using autopilot. At 800 m/s the large main chute will also deploy automatically. At the same time the drogue will collapse to get out of the way of the main chute. You need to release the drogue manually (control-D) as it is attached to the MTSV via a docking port. The heat shield and main chute also need to be released manually. Control of the rocket engines is by autopilot. When you're first learning to land it is best if you remain in cockpit mode in the MTSV. Once you're familiar with the landing technique you can take a look at the scenery!

Here is a more detailed description of the actions you will need to take:

Once the scenario starts it is best to bring up the docking port menu by pressing CTRL-D. Then you need to select docking port 4 where the drogue is docked. Don't press enter just yet...........wait until 35 seconds into the scenario and then press enter. This will release the drogue chute from the MTSV. The next operation that has to be conducted manually is the release of the heat shield. This should be done once the engines start up. At that point the vehicle will be decelerating fast enough to allow positive separation with the shield. The hover engines start up at an altitude of 1600 m so you need to watch out for this on the HUD (upper right green box) for that number. Alternatively you can keep an eye on the thrust level. In any case you need to release the shield the moment the engines fire.

Again, as for the drogue chute release, it is best to bring up the docking port menu again as early as possible for heat shield release. Select docking port 2. This is the port the shield is attached. You should expect to release the shield at about 120 seconds into the scenario. Things will happen quite quickly after heat shield release. The first thing to watch for is the main chute release altitude. The MTSV must release the main chute to enable it to maneuver and avoid the terrain near the landing site (using its rocket engines). This requires a manual operation which will be explained in a bit. Secondly, shortly after main chute release, the autopilot will pilot the MTSV towards a soft touchdown near the ERV. This may need some simple manual intervention for an accurate landing. It is best to not to worry about this during your first landing attempt but concentrate on the main chute release.

This is how the main chute is released. Bring up the docking release menu using CTRL-D. Then select docking port 3. The chute should be released at an altitude of 400 m by pressing enter. The altitude can be monitored on the HUD. Also you will get an audio cue if you have Orbiter sound installed. You should expect to release the main chute about 130 seconds into the scenario or about 10 seconds after heat shield release. Once the chute has been released the MTSV should level out at about 200 m and descend slowly to 150 m, using its hover engines. Autopilot should then turn you so your velocity vector will be pointing at the ERV. You should see a circle with a cross inside drift to the centre of your screen. You may not be able to see the ERV because of your altitude but it should be something like 200 m away. You can monitor the distance to the ERV by looking at the second row in the autopilot MFD on your right. This distance will vary a little depending on when you released the chutes and shields.

Once you are pointing at the ERV the autopilot will increase the main engines so you are travelling to the ERV at 5-10 m/s. Once you are 50 m away the retro engines will fire. Sometimes the MTSV overshoots the ERV and brakes on the other side, 50 m away. In any case you should see your velocity drop to about 1 m/s which is actually your descent rate. If you are above this after braking (say 2 m/s) it is best to trim your velocity by firing the retro engines for a bit (numpad minus) until your velocity reads some value close to 1 m/s (e.g. 1.1 m/s). You have until your altitude reaches 100 m to do this (maybe about 10 seconds or something) after which time your descent will speed up greatly.

At 30 m the engines will increase thrust for a soft landing and your landing gear will automatically deploy. You may find yourself hovering for a brief period before touching down.

Happy landings!

6. Limitations and Cautions

This add-on (with the help of some others) simulates the major aspects of the *Mars for Less* mission plan. In principle, the whole mission could be run end-to-end over a simulated ~5 year period, with launches of all six ERV components, ERV assembly in LEO, ERV flight to Mars, landing to establish the base, then (2 years later) launch and assembly of MTSV, crew launch to join MTSV, flight to Mars, aerobraking, landing, and finally launch of the ERV and return to Earth. We set up scenarios to do all of these major steps and even connected some of them. But in practice, we did not do a single end-to-end mission, in part because of some limitations with our spacecraft simulations. Some of these things could probably be overcome with custom DLL modeling, but not easily with Vinka's spacecraft DLL system (which in all other respects is excellent and easy to use).

For example, the MTSV ship is assembled from 5 modules (4 propulsion plus MTSV which is actually launched in two sections). Each propulsion module has its own RCS (thruster) system for use in maneuvering for rendezvous and assembly, and in a real spacecraft, the RCS systems of the 5 propulsion modules and the MTSV would certainly be integrated for efficient control of the assembled unit. But they are not integrated in the docked assembly simulated in Orbiter. As a result, maneuvering such a large stack of modules all docked together is impossible with RCS thrusters at normal values, and to be of use in the early boost phases of the mission, their thrust value had to be increased by 10x. This works but is wasteful of fuel and if not handled carefully can easily use too much. A workaround is to use Orbiters unlimited fuel setting until just before the TMI burn, quit the scenario and begin again with limited fuel this time. This is repeated before each boost phase of the mission.

7. Terminology and Acronyms

EDL – Entry/descent/landing
ERV – Earth Return Vehicle
HLLV – heavy lift launch vehicle (~100+ mt class)
ISRU – in situ resource utilization (e.g., making fuel from local resources, such as Mars' atmosphere)
LEO – low Earth orbit
MFL – Mars for Less
MLLV – medium lift launch vehicle (25 mt class)
mt – metric tonne (1000 kg)
MTSV – Mars Transfer and Surface Vehicle
TMI – trans-Mars injection
MFD – Multi-Function Display

8. Credits

The authors would like to thank Dr. Martin Schweiger for creating Orbiter and for making it available to the public. We also want to thank the members of the MarsDrive Consortium and the Orbiter community for their inspiration and help. There are also a number of Orbiter add-on makers we would like to acknowledge, starting with Vinka, whose spacecraft.dll modules made this and many other add-ons possible without custom programming, and António "Simcosmos" Maia who created a customized MFL version of his CLV launcher project. We also made use of a number of other Orbiter add-ons and wish to thank their makers (this list is in no particular order – on-line names used in quotes when a real name is not readily available). Orbiter Sound 3.0 (Daniel Polli), Interplanetary MFD (Jarmo Nikkanen), Ariane-5 original model (Thomas Ruth), Vallis Dao 3D Mars terrain ("jtiberius"), Tether MFD ("MattW"), Kourou launch site ("Papyref" and "Mustard"), NASA CEV (Franz Berner), astronauts and miscellaneous 3D objects (Greg Burch), Autopilot 1.7 (R. Bumm), and Flight Data Recorder MFD (Matt Weidner). For additional information on the *Mars for Less* Project for Orbiter and the add-ons that are used with it, please visit http://www.aovi93.dsl.pipex.com/mars_for_less.htm.