Multi Domain Vehicle Proposal

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Contents

1.Introduction

This document outlines a proposal for the development and manufacture of a fleet of Multi Domain Vehicles (MDV) to provide a low cost, safe and reliable transportation system to the Moon's surface, for both manned and cargo missions. The MDV is a development of the high-performance, rescue Personal Spaceplane, described in chapter 14 of the book:

EmDrive. Advances in Spacecraft Thrusters and Propulsion Systems

Roger Shawyer. CRC Press 2024

The enabling technology for this system is fourth Generation (4G) EmDrive propulsion.

The overall programme comprises eight phases with a schedule illustrated in Fig.1.

	Programme Phase	Year													
		1		2		3		4		5		6		7	
1	UAV development	■	■	■											
2	4G Head-start Work			■											
3	MDV development				■	■	■	■	■	■					
4	PAV development				■	■	■	■							
5	PAV commercialisation								■	■	■	■	■	■	■
6	MDV Qualification										■	■			
7	MDV Fleet manufacture										■	■	■	■	
8	MDV Initial Operation												■	■	■

Fig.1

The first phase is the development of an Unmanned Aerial Vehicle (UAV) to provide a demonstration of the lift capabilities of second generation (2G) superconducting EmDrive technology. 2G EmDrive comprises a superconducting EmDrive cavity without acceleration compensation. The Q value achieved by a 2G thruster is limited by the uncompensated Doppler Shifts, which occur during acceleration.

The UAV is described in section 3, with the development programme schedule of 18 months, and Budget of £20 Million, detailed in section 4.

12 months into phase 1, it is proposed to start a short Head-start work package, (Phase 2), to demonstrate the principles of 4G EmDrive. This will be carried out using a linear air track to measure the UAV engineering model (EM) thruster performance, under high acceleration conditions.

Once the UAV has completed a set of demonstration test flights, the MDV development programme, (Phase3), can start. This is estimated to take 3 years at a projected cost of £500 Million, and will result in an unmanned return flight to the moon.

The unmanned demonstration flight will be followed by a series of unmanned and manned flights to complete a Qualification programme, (Phase 6), to meet the regulations defined by the launch country.

Concurrently with phase 6, a manufacturing programme, (Phase 7), to produce a fleet of up to a further 4 spaceplanes will be started, at a rate of one every 6 months and a projected cost of £200 Million each.

A minimum fleet of 3 spaceplanes will enable initial operation of manned and cargo flights to build a permanent base on the moon's surface and provide tourist flights. One spaceplane will always be on instant availability for rescue, which will be a mandatory requirement for tourist flights.

The Personal Air Vehicle (PAV) development programme, (Phase4), could start at the same time as the MDV development. The two vehicles both use a 2-cavity thruster design, but the PAV uses four fixed 1.5GHz thrusters and a simple quad-copter flight control system thus significantly reducing development costs. The MDV uses four larger 950 MHz thrusters mounted on 2 axis gimbal mechanisms, giving much greater thrust and manoeuvrability. The PAV development would take an estimated 2 years, costing £100Million, and result in a first flight of a prototype air taxi. A PAV commercialisation programme would follow, with the aim of licensing a mass produced air taxi with an estimated price of £60 thousand. The manufacturing process would be similar to that used for a current hydrogen fuelled car. The PAV would provide early public familiarisation with EmDrive vehicles, and enable a revenue stream to finance the qualification of the MDV.

2.Project Organisation

It is assumed that the project would be organised with the lead company and manufacturer of the spaceplane, Aron Flying Ship Ltd, being based in South Korea, and the EmDrive engine prime contractor, Gilo Industries Ltd, being based in the UK. This organisation should enable the EmDrive technology export licencing to be readily agreed between the appropriate government departments in each country.

Thus for initial planning purposes, the following two task lists have been prepared.

Task list 1. Aron Flying Ship Ltd

1. Establish spaceplane design group.

2. Prepare preliminary designs for the PAV and MDV.

3. Carry out a Preliminary Design Review (PDR) with all interested parties.

4. Update EmDrive engine requirement specification based on PDR results and the progress of the UAV Demonstrator programme.

5. Carry out detailed designs of the PAV and MDV, incorporating a computer aided design and simulation programme.

6. Carry out wind tunnel tests to verify aerodynamic performance of both vehicles.

7. Complete design simulation programme of the MDV, with in-space attitude and control performance, and a Moon landing simulation.

8. Carry out a Critical Design Review (CDR) to include results of 4G Head start programme.

9. Manufacture and test of unmanned demonstrator vehicles

10.Start PAV commercialisation programme

11. Carry out qualification Test programme of the MDV, including manned Moon landing.

12. Start fleet manufacturing programme.

13.Start initial commercial operation of spaceplane fleet.

Task list 2. Gilo Industries Ltd

1. Establish EmDrive design group and obtain export licence.

2. Design UAV engine and test rigs.

3. Design UAV airframe.

4. Manufacture UAV engines and airframe.

5. Carry out UAV demonstrator tests.

6. Provide PDR input.

7. Carry out 4G headstart programme.

8. Design PAV and MDV engines.

9. Provide CDR input.

10. Manufacture flight engines.

11. Carry out engine qualification programmes.

12. Start flight engine production.

3.UAV Demonstrator

The purpose of the UAV is to demonstrate that EmDrive flight is possible using a simple low cost vehicle, illustrated in Fig.2.

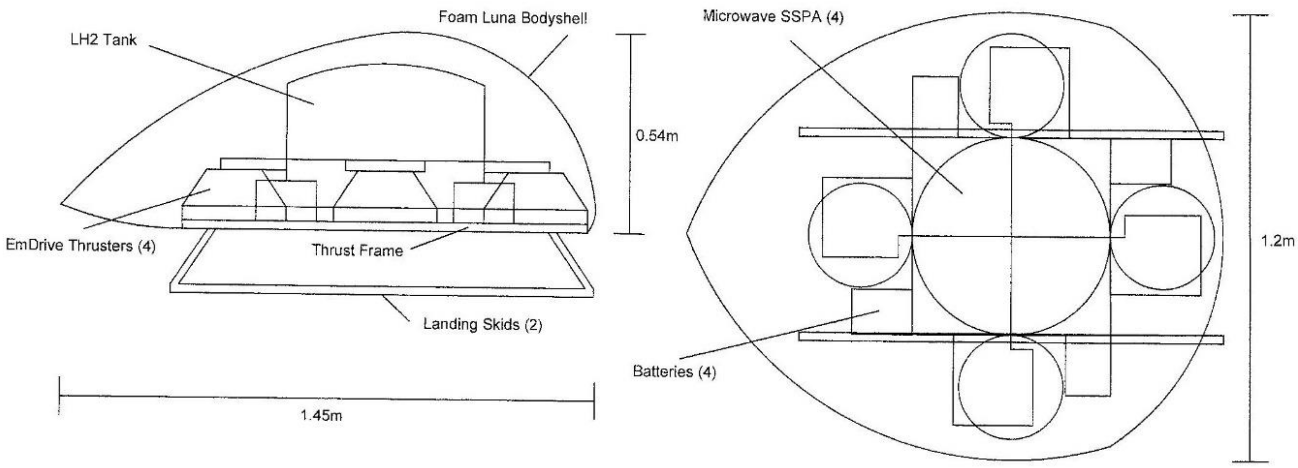


Fig. 2

The 62.5kg UAV is based on a lightweight thrust frame carrying four 2G thrusters with their associated Solid State Power Amplifiers (SSPAs) and batteries.

The thruster design is based on a 2.45GHz cavity operating in TE211 or TE213 mode. Yttrium Barium Copper Oxide (YBCO) thin film end plates are used, which give superconducting operation when cooled with liquid Hydrogen (LH2). This ensures the high Q value required for the specified thrust output of 463N/kW, at an acceleration of .05m/s^2.

Each SSPA incorporates a microwave signal generator and frequency control system and is powered by a 24 Volt, 16 Ampere Hour Lithium Polymer battery. The output section of the SSPA comprises a circulator, a load, and forward and reflected power sensors. The SSPA is rated at 500W minimum output power, and is cooled by the Hydrogen gas which boils off from the cavity cooling system.

A 50 litre thin walled stainless steel tank contains the LH2 supply, which is pressure fed to the cavities via control valves, operated by a control system monitoring the cavity temperature. Additional diverter valves are used as part of the temperature control system of the SSPAs. The hydrogen gas is then vented from the top of the UAV. Internal pressure within the tank is maintained by a safety relief valve.

The Flight control system is based on a standard radio controlled quad-copter system, giving pitch, roll and yaw control by varying the individual thrust of each of the four thrusters. Full telemetry of the propulsion system test data will be incorporated.

The UAV body-shell will be formed of thick foam to provide thermal insulation to limit liquid hydrogen boil-off.

Initial test flights will be carried out at the manufacturing site, with later demonstration flights covering a maximum range of 1.6miles at an altitude below 400 feet. All flights will be within range of sight of the operator, and will be limited to a maximum flight time of 12 minutes, before a refill with LH2 and recharging of the batteries is required. A maximum velocity of 11mph is predicted with a maximum acceleration of .005g.

4.UAV Programme

The 18 month UAV development programme is considered a challenging schedule, and will require a rapid start up, highly paid contract specialist engineering staff, and close project management. A significant proportion of the work will be carried out by sub-contractors who are experienced in microwave and cryogenic engineering. These conditions are typically found in space programmes, particularly military satellites when there is an urgent operational requirement.

WP No	Work Package	Month																		Resource	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Key Staff	Sub cons
1.1	Project Start Up	■	■	■																PC	
1.2	Project Management & Reporting				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	PM PS QA	
2.1	Thruster Design	■	■																		
2.2	SSPA Specification			■																ME MPE	
2.3	EM1 & EM2 Cavity Design	■																		PC	
2.4	Static Test Rig Design	■																		MeE	
2.5	Cryo System Specification			■																TE PE	WC
2.6	Vehicle Design				■	■	■													AE	
2.7	Flight Control System Specification						■													AE	
2.8	Dynamic Test Rig Design							■												MeE	
3.1	EM1 &EM2 Cavity Manufacture		■	■																PC	CE
3.2	Static Test Rigs Manufacture			■																PC	
3.3	EM1 & EM2 Cavity Tests				■	■	■													2ME 2MT	
3.4	FM1 Cavity Manufacture							■												PC	CE
3.5	FM1 Cavity Tests							■	■	■										ME MT	
3.6	FM2 to FM5 Cavity Manufacture									■	■									PC	CE
3.7	FM2 to FM5 Cavity Tests											■								ME MT	
4.1	SSPA1 & SSPA2 Procurement (EM)				■	■	■	■												MPE	MA TMD
4.2	MW Test Equipment Procurement	■	■	■																MPE	
4.3	FM SSPA Procurement (6 off)											■	■	■						MPE	MA/TMD
4.4	Cryo System Procurement				■	■	■													PE	WC BOC
5.1	FM1 Thruster Assembly								■											ME MT	
5.2	FM1 Thruster Static Tests									■	■									ME MT	
5.3	FM1 Thruster Dynamic Tests											■	■							ME MT	
5.4	FM2 to FM5 Thruster Assembly												■	■						2ME 2MT	
5.5	FM2 to FM5 Thruster Static Tests														■					2ME 2MT	
6.1	Vehicle components proc							■	■	■	■	■	■							AE PE	
6.2	EM Vehicle Assembly									■	■									2AE 2AT	
6.3	EM VehicleTests											■	■	■	■					2AE 2AT	
6.4	FM Vehicle Assembly													■	■	■				2AE 2AT	
6.5	FM Vehicle Flight Tests																■	■	■	2AE 2AT	

Fig.3

However it is recognised that the principles underlying EmDrive operation are not yet well understood. It is therefore recommended that once the core technical and management team have been assembled, they should attend an EmDrive Design Course. This could be run at the Prime Contractor premises and is envisaged as a 5 day intensive course.

An outline of the project plan is given in Fig.3, with a resource key given in table 1, and a list of potential sub-contractors for a UK based programme given in Table 2.

Two Engineering Model (EM) Cavity designs will be developed in parallel with separate engineering teams and test rigs. The best performing cavity will then be selected for Flight Model (FM) manufacture and test, where the dual teams and test rigs will facilitate rapid production of the six thrusters. Two thrusters will be used as spares.

An Engineering Model Vehicle will be manufactured and tested using small air turbines in place of the EmDrive thrusters, and used to develop Flight Control software and to test flight procedures.

An outline budget is given in Table 3.

Key	Staff Requirement	No
PC	Prime Contractor Staff	
PM	Project Manager	1
PS	Project Secretary	1
QA	Quality Manager	1
ME	Microwave Engineer	2
MPE	Microwave Procurement Engineer	1
MeE	Mechanical Engineer	1
TE	Thermal Engineer	1
CE	Control Systems Engineer	1
PE	Procurement Engineer	1
AE	Aircraft Engineer	2
AT	Aircraft Technician	2
MT	Microwave Technician	2
	Total	16

Table 1

Key	Sub-Contractor
WC	Wessington Cryogenics
MA	Microwave Amplifiers Ltd
TMD	TMD Technologies
CE	Ceraco GmbH
BOC	British Oxygen Company Ltd

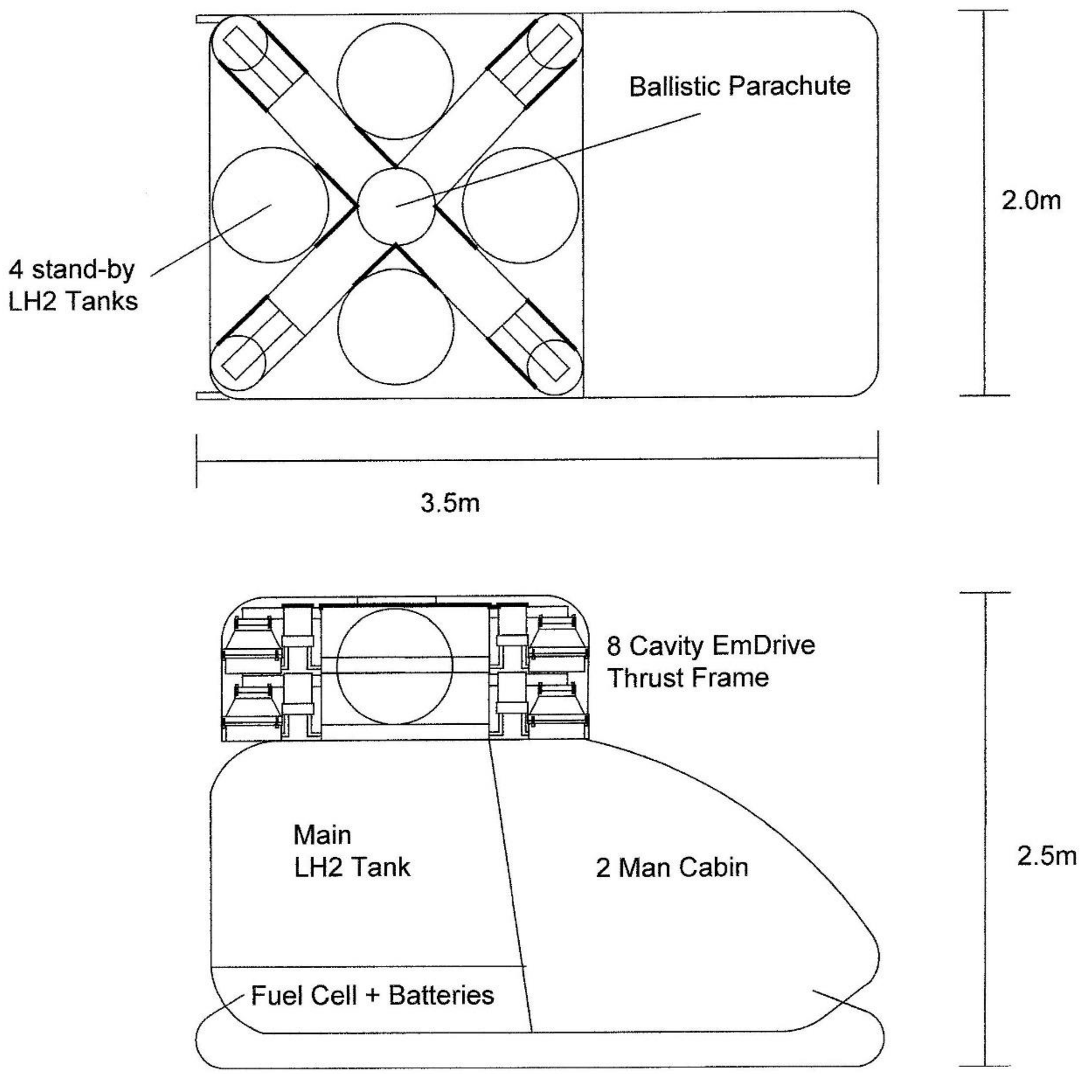
Table 2

Budget	£Million
Project Staffing	3.2
Design, Consultancy and Licence	0.8
Microwave Test Equipment	0.4
Test Rig Components	0.2
SSPA EM development (2 off)	1.0
SSPA FM (6 off)	0.6
Superconducting Components	0.2
Cryo System development	1.0
FM Cryo System	0.5
LN2 and LH2 Supply	0.1
Flight Control Components	0.3
In-House Manufacturing	1.5
EM Vehicle Components	1.0
FM Vehicle Components	1.5
Flight Test Support Equipment	0.5
4G Head-start Work	2.0
Project Costs	14.8
Contingency (20%)	3.0
Profit (15%)	2.2
Total Price	20.0

Table 3

5. PAV Description

The Personal Air Vehicle, shown in Fig.4 is a simple 2 person air vehicle aimed at the air taxi market. The flight controls would be an update of the UAV system with autonomous operation as an option. Total take-off mass is 940kg with a maximum velocity of 230 km/hr and a maximum acceleration of 0.4g. The 2,400 litres of LH2 feeding the fuel cells give a maximum operating time of 2.5 hours. The thrust frame comprises of eight LH2 cooled 1.5GHz thrusters, giving 2 for 1 redundancy. Four stand-by LH2 tanks (together with emergency batteries at the base of the vehicle) allow 10 minutes operation for an



emergency landing. A ballistic parachute is incorporated for an all-engine out situation.

Fig 4. Personal Air Vehicle

6. MDV Description

The Luna MDV is one of a family of vehicles based on a four engine, thrust frame, and weighing up to 26 Tonnes. The Orbital version, used for a Moon landing mission, is shown in fig.5.

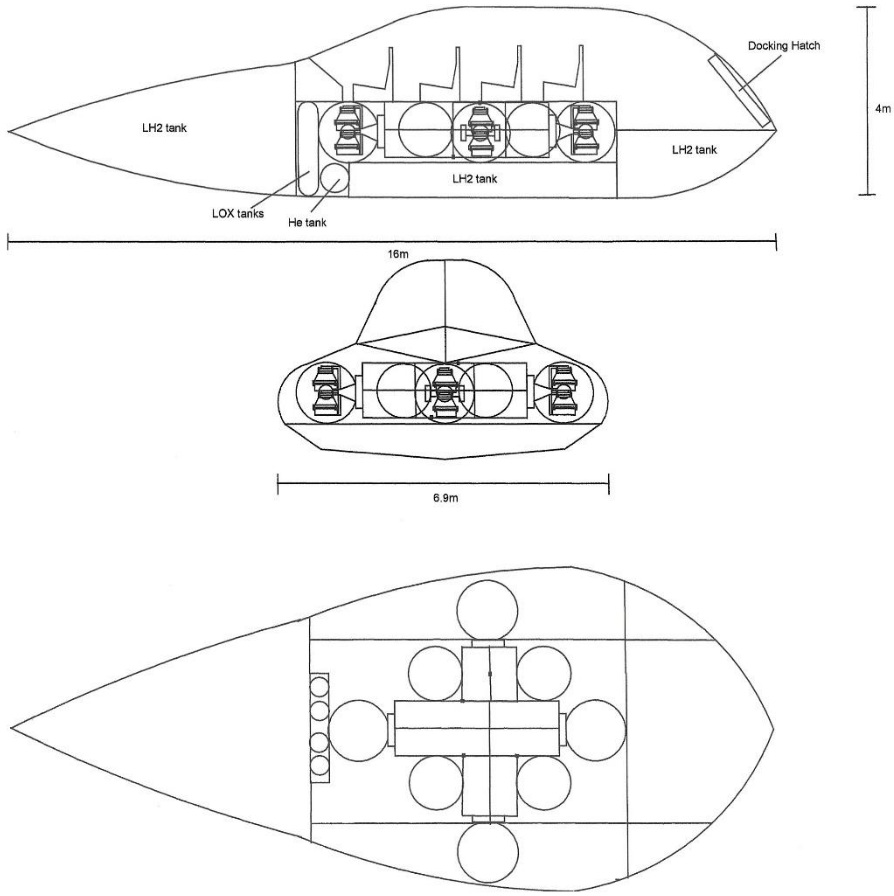


Fig.5.Orbital/Moon Version of Multi Domain Vehicle

The Orbital version would include an 8 person cabin with full life support equipment and a passive docking hatch at the rear, which is compatible with the NASA International Docking Adapter-2. An outline plan of the cabin is shown in Fig.6, and it is proposed that the 8 seats can be folded down to give a volume large enough for passengers to enjoy a zero gravity experience during the cruise part of their flight.

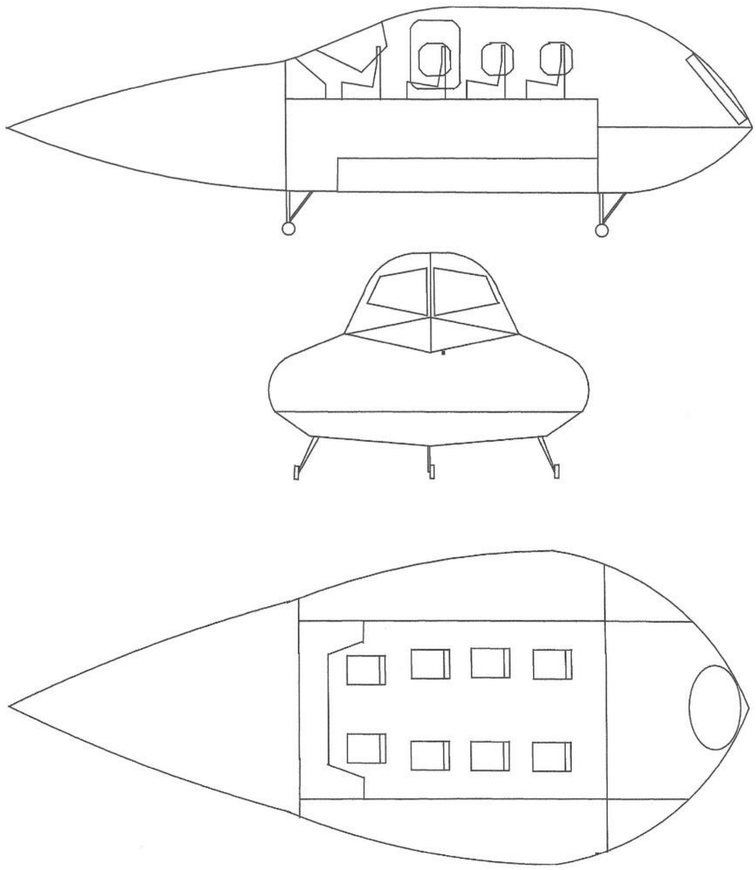


Fig.6. Multi Domain Vehicle outline Showing Cabin Layout

To obtain full space qualification for a manned spacecraft, the spaceplane needs multiple operating modes to cover mission emergencies.

The four engine configuration, with interconnection of power amplifiers and fuel cells gives full redundancy. The maximum thruster power rating enables an emergency vertical landing to be undertaken with only one engine functional, albeit in a non-normal vehicle attitude.

Multiple Liquid Hydrogen and Liquid Oxygen tanks, and a generous fuel margin, enhances safety. The thrust frame includes a residual Liquid Hydrogen tank for each engine, to maintain the required cryogenic temperature, during turn around and routine maintenance periods on the ground.

For an all-engine out emergency, the aerodynamic body would provide sufficient lift for a horizontal glide landing following deceleration and descent to a low altitude. Control surfaces (elevons) on the upper and lower parts of the rear airframe would provide pitch, yaw and roll control as well as air brakes. In this emergency, a fast helium purge system would empty the main Liquid Hydrogen tanks and give the vehicle high crash worthiness. The empty tanks, with internal bladders, would then provide good buoyancy for a crash landing on water.

Note that as its name implies, the Multi Domain Vehicle could also take off and land vertically on water, and could easily manoeuvre for docking. The vehicle would be capable of skimming just above the water surface at high speed.

Any mission emergency in space that required crew and passenger escape, would use a standby spaceplane, and adopt high acceleration levels to enable rapid rendezvous. Rescue would be via the docking adaptor. The high levels of manoeuvrability given by the four 2-axis gimballed engines in all spaceplanes, would enable fast approach and docking procedures.

Lower cost versions of the spaceplane, would be for global passenger and freight transport, using sub-orbital flight profiles. These would only require a pressurised cabin, whilst short route, air taxis versions, would require no pressurisation and would only be required to meet general aviation regulations. This full family of vehicles, including military versions, would enable large scale production and low individual vehicle costs.

7. Moon Landing Mission

A mission analysis was carried out for the original Personal Spaceplane (PSP) for a manned Moon landing and return. The results from the analysis were published in chapter 14 of the EmDrive book referenced in section 1.

For the PSP, a payload mass of 5,000 kg was assumed, to cover cabin, 6 passengers and life support equipment. The total vehicle dry mass was 19,554kg and the maximum fuel mass was 2,861Kg, leading to a launch mass of 22,415kg. A total flight time of 262 minutes (4 hours 22 minutes) was calculated for the outward flight and Moon Landing.

The vehicle attitude at launch is horizontal, (+X vehicle axis), with acceleration in the vertical (-Z vehicle axis) direction. A 90 degree rotation is then made, to give a vertical acceleration along the vehicle +X axis. Local reference axes for the spaceplane are shown in Fig.7.

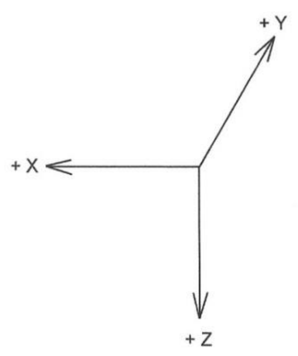


Fig.7. Local reference axes for spaceplane.

An acceleration of 1m/s/s is maintained until an altitude of 100km is reached. This minimises drag, which is a maximum of 2,161kg at an altitude of 10km and a velocity of 100m/s (225mph).

Once clear of the atmosphere, acceleration increases to 9.81m/s/s (1g) until a distance of 150,000km from Earth is reached. At this point, the acceleration drops to zero and the vehicle is in cruise mode. This flight path optimises fuel usage. A rotation of 180 degrees is made to align the vehicle for the deceleration phase. Cruise lasts for 96 minutes, and during this period the passengers will experience zero g. At 310,000 km from Earth, deceleration at 9.81m/s/s will start, reducing to 2.61m/s/s at 360,000Km from Earth. A vertical landing is carried out, in the same horizontal vehicle attitude as at launch, at a distance from Earth of 384,415km, after a total flight time of 262 minutes (4 hours 22 minutes).

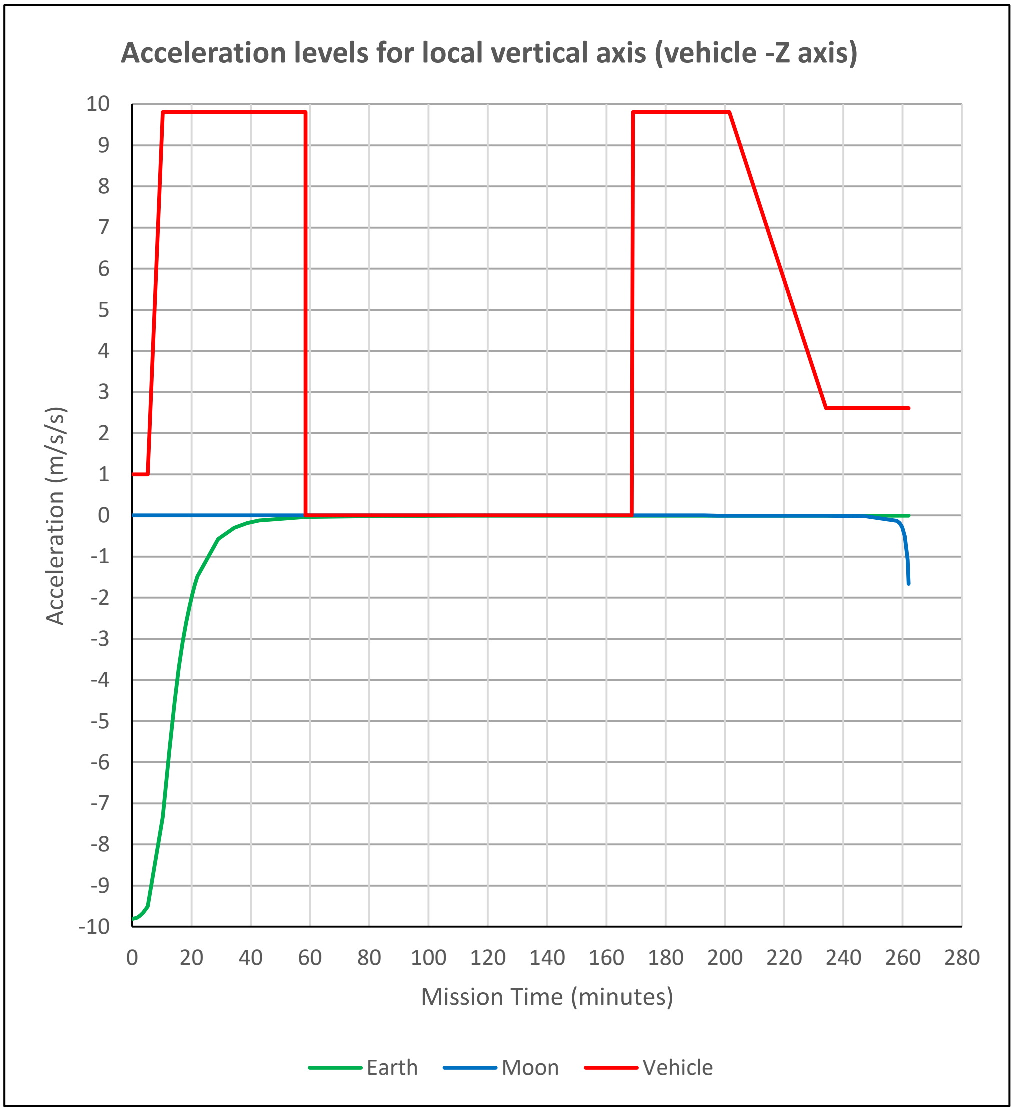


Fig. 8. Acceleration levels for Earth, Moon and Vehicle

The acceleration levels referenced to the local vertical, vehicle -Z axis, are shown for Earth, Moon and Vehicle in Fig 8.

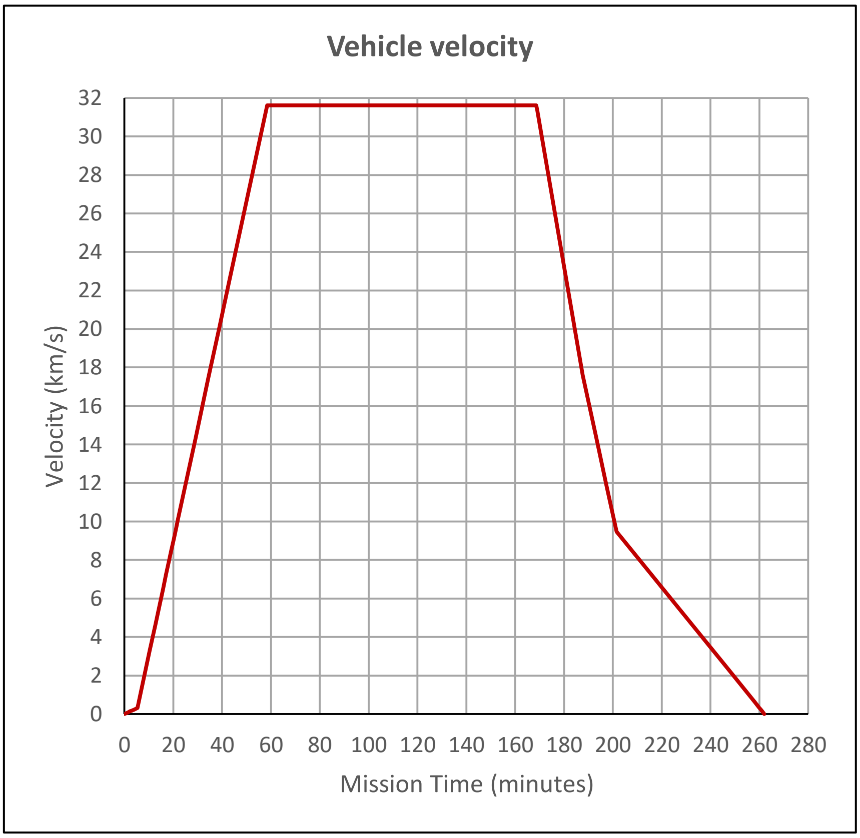


Fig. 9. Vehicle velocity for Earth to Moon Flight.

Vehicle velocity and fuel usage are illustrated in Figs 9 and 10.

For the MDV, the 8 passenger capacity increased the assumed payload mass to 6,700kg, and the fuel capacity was increased to 5,076kg. This gives an estimated launch mass of 26,432kg. For the same flight plan as the PSP, the total fuel used by the MDV for the outward flight is calculated as 1,543kg. For simplicity, the total mission fuel used is assumed to be twice the Earth to Moon flight. Thus a conservative fuel margin for the full mission is 39%. Note that the forward LH2 tank would be separated into two tanks of approximately equal volume. Thus with a total of four LH2 tanks and four LOX tanks, the loss of fuel from any one tank would not jeopardise the mission.

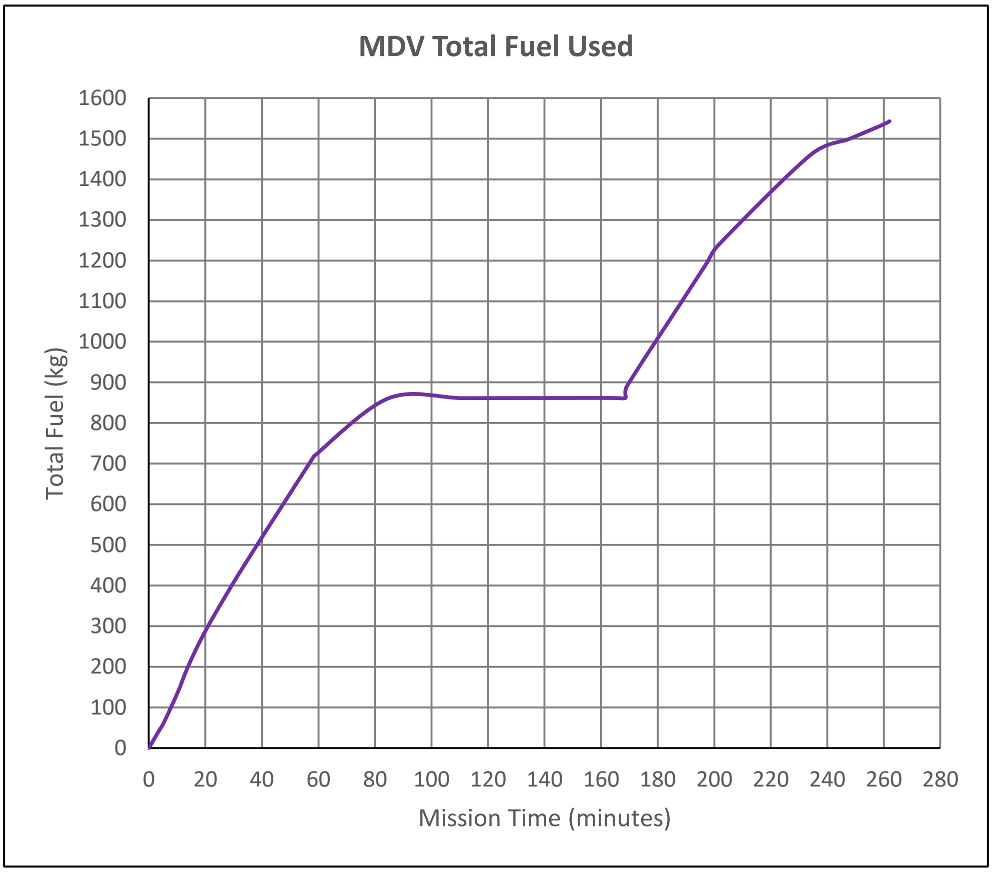


Fig. 10. Total fuel used for Earth to Moon Flight

7.Operational Considerations

The overall dimensions of the manned module are 10m x 3m with a maximum height of 2.6m. This gives a relatively spacious internal cabin, allowing for 8 reclining seats, hygiene compartment, and spacesuit stowage, together with controls and life support equipment.

A typical crew would consist of one company pilot, one flight attendant and 6 paying passengers. They would be transported in reasonable comfort to and from habitation modules on the Moon's surface, which would form a Moon base for scientific and tourism purposes. It is envisaged that for paying passengers, training would consist of a medical, followed by a few days of spaceplane familiarisation and safety procedures. Spacesuit fitting and training would be necessary, as transfer from the spaceplane to a habitation module may involve a Moonwalk. Finally rescue training would be mandatory, which would include recovery from a simulated emergency landing on water.

The ground facilities for a fleet of 5 spaceplanes would comprise two 11,000 sq ft buildings. The buildings would be one Flight Hanger and one Service Hanger. The Flight Hanger would accommodate up to 3 spaceplanes, and be used for fuelling, loading and first line maintenance. Due to the presence of Liquid Hydrogen and Liquid Oxygen this building would be classed as a Hazardous Area and be subject to special safety conditions.

The Service Hanger would enable routine servicing to be carried out on up to 3 spaceplanes and accommodate mission control and staff facilities.

As launch and landings are purely vertical, the actual launch and landing site would be no more than a small area of tarmac close to the Flight Hanger. The only need to site the facility at an existing airport or spaceport would be the need to obtain a controlled airspace.

Mission analyses show that a sub-orbital version of the spaceplane would attain a useful velocity of say 5 km/s within 15 minutes. This would put flight times for global distances at around an hour. The velocity of an MDV air taxi, with a maximum 5,000 ft altitude, would be limited by air drag to a few hundred mph. This would nevertheless serve the regional air transport market, without the need for regional airports.

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