Spaceflight Revolution

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Spaceflight Revolution

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Published by

Imperial College Press
57 Shelton Street
Covent Garden
London WC2H 9HE

Distributed by

World Scientific Publishing Co. Pte. Ltd.
5 Toh Tuck Link, Singapore 596224
USA office: Suite 202, 1060 Main Street, River Edge, NJ 07661
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

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ISBN 1-86094-320-9

ISBN 1-86094-325-X (pbk)

Typeset by Rocket Media, Flax Bourton, Bristol, England. Info@rocket-media.co.uk

Printed by FuIsland Offset Printing (S) Pte Ltd, Singapore

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PREFACE

The genesis of this book goes back to a spring day in 1960 during my final year as an aeronautical engineering student in London at Imperial College. I was being interviewed for a job with the Hawker Siddeley Aviation Advanced Projects Group. The conversation went something like this:

"How did you come to this interview, my boy?"

"I cycled, sir".

"I see. How much cycling would you do if your bike were scrapped after each ride?"

"Er, not much, sir".

"Quite right, my boy. Well, that is how it is with launching satellites. They are carried on converted ballistic missiles that can fly only once. Very expensive. We are going to add wings, a tail, a cockpit, a heat shield and landing gear, and fly them back. All you have to do is refuel them and fly them again, just like an aeroplane. Greatly reduced cost. Greatly improved reliability. Obvious, isn't it?"

I must have looked duly impressed by the power of this logic, because they offered me a job as an aerodynamicist in the hypersonics team. I accepted this offer and started in 1961 after a year at Princeton doing post-graduate research on rocket motors. I would probably have taken another job if I had known that, forty-two years later, all satellites would still be launched by largely expendable vehicles, and that I would be writing a second book trying to revive this 1960s dream. (The first, *Your Spaceflight Manual - How You Could be a Tourist in Space Within Twenty Years*, was co-written with Dr Patrick Collins and published by Headline in 1990.)

For a few years, the job was as interesting as the interviewer (John Allen, who still remembers his patter) had promised. We were planning aeroplanes

that could fly to and from orbit to replace the ballistic missiles then being used to launch satellites, as well as airliners two or three times faster than Concorde and sub-orbital airliners that could fly from New York to Tokyo in 75 minutes. We were planning a great advance in aeronautics and astronautics. Most large aerospace companies at the time had comparable ideas. In the United States, the X-15 research aeroplane was demonstrating the required technology by flying regularly to a height greater than 50 miles (80 km) which is usually considered to be the lower limit of space.

This great advance has never happened.

Space policy was diverted by the pressures of the Cold War into using throwaway vehicles for carrying people to space, and it is still stuck in the same rut. Even the Space Shuttle failed to meet its promise of reducing the cost of access to space because it was built far more like a ballistic missile than an aeroplane. The X-15 remains the only fully reusable vehicle to have been to space and back.

The present way of doing business is rapidly becoming untenable, and a return to the plans of the 1960s is likely soon. A rapid catching up is possible, using technology since developed for other projects. Among the benefits of the spaceflight revolution would be that in about ten years from now most people who are reasonably fit and affluent will be able to take a brief trip to space. The book explains what could have happened, why it did not happen, and how and why it is likely to happen soon. The predictions are based on straightforward and robust assumptions and analysis, using simple first-order sizing and costing comparisons. The derivation of some of the results is provided in the appendices, for those who wish to delve further.

I should declare a commercial interest in that I have kept an involvement with launch vehicles and now run a small company that has plans to develop a

small spaceplane. I have done my best to prevent this from biasing the argument. If anyone feels that the result is unfair, by commission or omission, I hope they will accept that this is more of an exposition than a source book. They are most welcome to comment. An open debate on the way ahead for space would benefit us all.

I am greatly indebted to friends and colleagues in the small but rapidly growing space tourism movement for their help and support over the years, and hope that they in turn will find this book helpful.

I would like to thank all those who have helped with this book, especially Mark Radice for much of the research, Professor Mark Birkinshaw for advice on space-based astronomy, Dr Patrick Magee for advice on medical aspects of spaceflight, Professor Ray Turner for advice on radiation in orbit, and Dr Robert Hall and Carol Pinchefsky for very helpful comments on the draft. Any misinterpretations of this advice are entirely my responsibility.

I would also like to thank various copyright owners for permission to use their illustrations.

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GLOSSARY

Ballistic Missile	Used here in the modern sense to refer to large rocket-powered guided weapons with no wings.
Carrier Aeroplane	The aeroplane-like lower stage of a multi-stage launch vehicle.
ELV	Expendable Launch Vehicle.
Fuel	The chemical substance that reacts in an engine with the oxidiser. In a rocket-powered aeroplane, 'Fuel' sometimes used loosely to mean fuel and oxidiser, i.e., all the propellant.
g	Used here to mean a person's apparent weight divided by that at the Earth's surface. A person at the Earth's surface supported by a chair, floor, etc., will 'feel' 1g. This feel is due to the restraint preventing him/her from falling towards the centre of the Earth, pulled by gravity, at an acceleration of approximately 9.8 metres per second per second. In orbit in a non-rotating spacecraft, there are no restraining forces, and the person will feel weightless, or experience 'zero-g'.
Hypersonic	Speeds faster than about Mach 5, or five times the speed of sound. At this and higher speeds, the shock waves are close to the aircraft surface, and aerodynamic characteristics do not change greatly between Mach 5 and orbital velocity, which is approximately Mach 25.
Ideal Mature Spaceplane	Used here to mean the most competitive spaceplane

design which could be built using technology at present at the stage of early demonstration.

Inert Mass

The take-off mass of an aeroplane or launcher can conveniently be divided into inert mass, propellant mass, and payload. The inert mass consists mainly of structure, engines, and equipment. In an expendable launcher, the heaviest structural items are the propellant tanks.

ISS

International Space Station.

Mach Number

Aircraft speed divided by the local speed of sound, which is about 340 m/s at sea level and 295 m/s in the stratosphere, depending on local temperature.

Mature

A new technology starts with research and then evolves through demonstration, prototype construction and early operations to mature operations. Cost and ease of use greatly improve during this maturing process. A mature spaceplane is defined here as one which is as good as an airliner in terms of safety, life, maintenance cost, and turnaround time.

Operational Prototype

Used here to mean an early development model of a new flying machine that is built in an experimental workshop and used for flight testing and some early operational missions.

Orbit

A trajectory of a small body in space around a large one which is periodically repeated, such as a satellite

around the Earth. Unless stated otherwise, refers to Low Earth Orbit, i.e., a more or less circular orbit round the Earth at a height of a few hundred kilometres.

Orbital Velocity

The horizontal speed needed for a body to circle the Earth in Low Earth Orbit. Approximately 8 km/sec. 'Velocity' used when direction is relevant, 'speed' when it is not.

Orbiter

The upper stage of a multi-stage reusable launch vehicle that reaches orbit.

Oxidiser

The chemical substance consumed in an engine that reacts with the fuel. In a jet engine, the oxidiser is the oxygen in the air. In a rocket engine, the oxidiser is carried on board the vehicle in a separate tank. It is often liquid oxygen or a chemical containing oxygen.

Propellant

Fuel and oxidiser carried in a vehicle for use in a rocket engine.

RLV

Reusable Launch Vehicle.

Rocket Engine

An engine in which fuel and oxidiser, both carried by the vehicle, combine chemically in a combustion chamber to generate a high temperature gas, which exits through a nozzle to produce thrust. 'Rocket' often used loosely to describe a complete rocket-powered vehicle that takes off vertically and is expendable, like a rocket firework, ballistic missile,

or conventional launch vehicle.

Space Height

As height above the Earth increases, the atmosphere becomes less dense. Space height is the height at which the atmosphere is deemed to stop and space to start. This is largely a matter of definition but, for aeronautical engineers, it is the height at which the air loads on a vehicle become very low. There are various definitions of space height. In the 1960s, the USAF awarded Astronaut Wings to X-15 pilots who exceeded a height of 50 miles (80 km). At this height, the sky is dark with bright stars even in daytime. At this height, air loads become significant on the Space Shuttle as it reenters the atmosphere from orbit. The Federation Aéronautique Internationale defines the edge of space as 100 km (62 miles). The FAI is the international body regulating aircraft speed and other records. The 'A' stands for Aéronautique rather than Astronautique, and its jurisdiction stops at 100 km. For present purposes, the 50 mile (80 km) definition is convenient. This is about seven times higher than the cruise height of jet airliners.

Spaceplane

Used here to mean an aeroplane-like fully reusable vehicle that can fly to and from space height and that lands using wings for lift. Unless prefixed by 'sub-orbital', refers to a vehicle that can fly to and from orbit.

Spaceplane Age	Used here to refer to the time in the future when spaceplanes have revolutionised space travel, much as the railways did to land travel.
Specific Impulse	A measure of rocket motor efficiency. The thrust produced for each kg of propellant consumed per second.
Stage	Launchers are an assembly of vehicle elements, all but one of which are discarded during the acceleration to orbital velocity. These elements are called stages. Each stage increases the velocity until orbit is achieved. A single-stage vehicle is theoretically possible, but has not yet been built.
Sub-orbital	A trajectory that reaches space height, but not sufficient speed to stay up like a satellite. Unless prefixed by 'long range', refers to a vehicle that spends only a few minutes in space and lands back at or near to where it took off.
Sub-orbital Shuttle Aeroplane	A 'thought experiment' modification of the Space Shuttle Orbiter, to enable it to take off down a runway unassisted by expendable components.
Turnaround Time	The time required at an airport terminal to unload an airliner, prepare it for the next flight, and re-load it.
Zero-g	A convenient term to describe the weightless conditions experienced in orbit in a non-rotating spacecraft. Strictly speaking, the 'g' is nearly always more than zero, and 'microgravity' is a more precise

term.

Zoom-climb

A flight manoeuvre in which speed is traded for height. The aeroplane starts at high speed in level flight, the pilot pulls it into a steep climb, and the speed drops off as height is gained. Zoom-climbs are a means of briefly reaching great height.