No Bucks, No Buck Rogers

Creating the Business of Commercial Space

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CP
Curtis Press

Derek Webber
Spaceport Associates

Distributed by Universal Publishers, Boca Raton

ISBN: 1627340912 (ISBN-10)
ISBN: 978-1-6273409-1-5 (ISBN-13)

First published 2017 by Curtis Press

Cover design: Jim Wilkie

Visit Curtis Press at *www.curtis-press.com*

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To the memory of those who lost their lives in creating the business of private human spaceflight and commercial space exploration:

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MIKE TYNER ALSBURY

Foreword

Sa'id Mosteshar, Director of the London Institute of Space Policy and Law

Although there exists a large archive of information about space exploration and development, most of it tends to focus on specific activities such as human spaceflight, the prime example being Moon exploration and the Apollo program. No one has yet traced the history of our engagement with the business of outer space in as comprehensive and engaging a way as Derek Webber. He has been involved in every aspect of the commercial space business sector, including technical, regulatory, policy, financial, marketing, and contractual, and is extremely well qualified to comment on its development and future direction.

Humanity's venture into outer space was not entirely spurred by our desire to explore it in a search for knowledge about the mysteries of the universe. Our initial efforts were more concerned with political and military purposes, such as the refinement of inter-continental missile capability. Discovery and exploration followed, along with the development of satellites in Earth orbit and the provision of more military applications. These included spy observation satellites to locate target sites and troop movements; navigation satellites that can provide precise troop and enemy locations; and satellites for communication with and between troops. Scientific satellites, although sowing the seeds of non-military space exploration, were however still largely funded and directed by government.

The early 1980s saw a growing private interest in space activity for commercial purposes. Communication satellites had already been employed as commercial ventures, owned and managed by governments, largely through intergovernmental organizations. The privatization of these ventures accelerated private involvement in what became lucrative space-based businesses.

Subsequently, private interest and government funding requirements have brought about many changes in the approach to the use of space. With the onset of the manufacture of cubesats and other small satellites, the proliferation of location and related services, and the development of multiple low-cost launchers, some of them even re-usable, the commercial space landscape has changed dramatically in a relatively short time.

Derek takes us expertly through these previous phases of space activity, including the transition from government to private space ventures or hybrid enterprises. However, that is not where it ends. He encourages us to consider future possible space commerce ventures yet to be developed, including space tourism, space solar power, asteroid mining, and concepts for the use of commercial space business revenues to fund travel across the inter-planetary void between gravity wells.

His book combines a data-rich focus on the progress in space technology and applications with a personal story of someone who was not only involved

at every stage, but who has lived and breathed the excitement of the human venture into outer space through a commercial perspective.

Derek's splendid choice of imagery and his easy style of storytelling, combined with his detailed inside knowledge of developments, make this book not only a thoroughly informative reference, but also a highly engaging and enjoyable read for anyone with even a passing interest in space.

Sa'id Mosteshar
Lincoln's Inn, London
October 2016

Thanks

With regard to what I have termed "traditional commercial space" in this book, I acknowledge the guidance of my former associate Blue Streak rocket engineers at what is now Airbus Defense and Space in Stevenage, UK—Bill Graham, Terry Curran, Geoff Pardoe, Bernard Eddleston and Gerry Beere. It was a great start to my 50 years in the business. Then, at the international satellite operator Inmarsat, in London, a debt of friendship is owed to my fellow members of the "Gang of Four" negotiating team, some of whose tales are recounted in this book—Peter Berlin, Alan Auckenthaler and Dominique Darricau—and to my Procurement Department staff. Later, at the satellite broadband provider Tachyon Europe in Amsterdam, my team—Simon Dickhoven, Jay Ginepri and Alberto Martini in particular—are thanked for providing me with strong backup while we together negotiated the challenges of managing a small high-tech entrepreneurial space engineering startup. We learned a lot together, very quickly, thanks to many brown bag pizza lunches

Following my 25 years in the satellite telecommunications business in Europe, in transitioning to the space tourism phase of my professional activities, once I came to the US permanently in 1993, I owe thanks to my consulting clients and particularly to the ASCENT and Futron/Zogby forecasting teams at Futron Corporation—supported by my two lieutenants Charles Murphy and Susie Beard—and to Phil McAlister, whom I had managed to persuade in the first place to contract for my services as project manager for those significant projects. We all of us in the commercial space business in the US owe thanks to Lori Garver, and to the late lamented Patti Grace-Smith, for their key leadership roles in converting the "new space" commercial space developmental dreams into government-backed reality.

In looking to the distant future of commercial space exploration, I have been constantly guided by the amazing Peter Diamandis, who has inspired me since he initially created the International Space University and a string of entrepreneurial engines of advancement in succession. The whole of sub-orbital space tourism would not have happened without him, as he created the Ansari XPRIZE, which led to SpaceShipOne's achievements. Now, as one of the nine international judges of the Google Lunar XPRIZE, I continue to expand on those achievements, as I work with my fellow judges to monitor a non-governmental mission to the Moon with $30M in prizes at stake. And now, as I continue to push the boundaries to make possible a technical and financially viable approach to interplanetary travel described in the book, I am grateful that the young members of my new team, the Gateway Earth Development Group (GEDG)—led by Katy Voisey, Matjaz Vidmar, Andrew Luers and Lawrence MacDonald—are ensuring that the future of commercial space exploration is in safe hands. Thanks to you all for agreeing to spread the word, and do the hard work necessary to build the economic case, for providing the kind of space architecture needed for the 21st century.

In preparing the book for publication, thanks go to Neil Shuttlewood of Curtis Press, who found ways to keep the main story coherent, whilst providing each reader with the detailed data needed for your respective purposes. Plaudits to Arlene Kelly of Vivid Art and Design who provided cover concepts and key charts. My dear wife Sarah Fisher has not only contributed one of her artworks, but has reviewed early drafts of the manuscript saving me from several embarrassments. Thanks to my daughter Grace Webber for never tiring of hearing the stories (now that they are in book form, maybe I can ease off on telling them to you all over again). Thanks to my good friend Sa'id Mosteshar, who ensures that I do not stray too far from the tenets of international space law as I do my work, who helped me launch the Gateway Earth Development Group initiative in Oxford, England, in 2015, and who graciously agreed to provide the Foreword. For the care and nurture of my two websites (below), thanks to my always-accommodating web guru Lauren Mier.

And finally a tip of the hat to two giants in the field who have always been supportive of my efforts: to Roy Gibson, the former first Director General of the European Space Agency, whose wisdom and droll humor have kept me delighted, informed and amused ever since we worked as colleagues at Inmarsat in London in the 1980s, and to Buzz Aldrin, who has never stopped promoting the cause of space exploration, and the role of commercial space in making it possible, since he got back from his Moon trip in 1969. Thanks to you both. When we finally get there, you will find that I named a crater for each of you on Mars.

All omissions and errors in the book are, of course, my own responsibility. The data has been provided on a consistent basis with the last full-year quantities being for 2015, and the last entries regarding company developments ending at July 1, 2016. I hope you find it to be a useful reference volume recording the state of the art just at the time of a massive paradigm shift in the space business, as we move from ''old space'' to ''new space''. Things will never be the same again. Please let me know of any errors that have found their way into the text, and I shall make sure they are corrected in later versions.

Ad Astra per Negotium

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Abbreviations

AIAA	American Institute of Aeronautics and Astronautics
AIT	Assembly, integration, and test
AM	Additive manufacturing
ARM	Asteroid Redirect Mission
ATC	Air traffic control
ATV	Automated Transfer Vehicle
BAe	British Aerospace
BEAM	Bigelow Expandable Activity Module
BIS	British Interplanetary Society
BREXIT	British Exit from the European Community
BSB	British Satellite Broadcasting
C3PO	Commercial Crew and Cargo Office
CCDEV	Commercial Crew Developments
CCiCAP	Commercial Crew Integrated Capability
CCN	Contract change note
CCR	Contract change request
CCTCap	Commercial Crew Transportation Capability
CDM	Configuration and data management
CDR	Critical design review
CGS	Centimeter, gram, second (system of units)
CNES	Centre National d'Etudes Spatiale
Comsat	Communications satellite
COMSTAC	Commercial Space Transportation Advisory Committee
COTS	Commercial Orbital Transportation Services
CPC	Certification products contracts
CPOD	Cubesat Proximity Operations Demonstrator
CRS	Commercial Resupply Service
CSLA	Commercial Space Launch Act of 1984
CSI	Constellation Services International
CSLAA	Commercial Space Launch Amendments Act of 2004
CXV	Crew Exploration Vehicle
DARPA	Defense Advanced Research Projects Agency
DBS	Direct Broadcast Satellite (or Service)
DOE	Department of Energy (US Government)
DRL	Data requirements list
DSI	Deep Space Industries
EADS	European Aeronautic Defence and Space Company
EIB	European Investment Bank
ELDO	European Launcher Development Organization
ELV	Expendable Launch Vehicle
ESA	European Space Agency
ESRO	European Space Research Organization

EUTELSAT	European Telecommunications Satellite Organization
EVA	Extra-vehicular activity (i.e., "space-walk")
FAA	Federal Aviation Authority
FAA-AST	FAA, Office of Commercial Space Transportation
FDR	Final design review
FRB	Failure Review Board
FRR	Flight readiness review
F/Z	Futron/Zogby Space Tourism Demand Study
GDP	Gross Domestic Product
GEDG	Gateway Earth Development Group
GEO	Geostationary Earth orbit
GLXP	Google Lunar XPRIZE
GPS	Global Positioning Service
GSLV	Geostationary Satellite Launch Vehicle
GTO	Geostationary transfer orbit
GWIC	Great Wall Industry Corporation
HD	High definition
HDTV	High definition television
HOTOL	Horizontal Take-Off and Landing
HSD	Hawker Siddeley Dynamics
IAA	International Academy of Astronautics
ICBM	Intercontinental Ballistic Missile
IGY	International Geophysical Year
ILS	International Launch Services
INMARSAT	International Maritime/Mobile Satellite Organization
INSAT	Indian National Satellite System
INTELSAT	International Telecommunications Satellite Organization
IOT	In orbit test
IP	Intellectual property
IPO	Initial Public Offering (of shares)
ISRO	Indian Space Research Organization
ISRU	In-situ resource utilization
ISS	International Space Station
ISU	International Space University
ITAR	International Traffic in Arms Regulation
ITB	Invitation to bid
ITU	International Telecommunications Union
JAXA	Japanese Space Research Organization
JSC	Johnson Space Center (NASA)
KSC	Kennedy Space Center (NASA)
LEO	Low-Earth orbit
LEOP	Launch and Early Orbit Phase
LONEOS	Lowell Observatory Near Earth Object Search
LOX	Liquid oxygen
LRRB	Launch Readiness Review Board

MAD	Mutually assured destruction
MARS	Mid-Atlantic Regional Spaceport
MDA	MacDonald, Dettwiler, and Associates (Canada)
Metsat	Meteorological satellite
MEO	Mid-Earth orbit (between LEO and GEO)
MEV	Mission Extension Vehicle
MIT	Massachusetts Institute of Technology
MOXIE	Mars Oxygen ISRU Experiment
MSFC	Marshall Space Flight Center (NASA)
NASA	National Air and Space Administration
NASM	National Air and Space Museum (Smithsonian)
NASTAR	National Aerospace Training and Research Center
Navsat	Navigation satellite
NEA	Near-Earth asteroid
NEAP	Near-Earth Asteroid Prospector
NEAT	Near-Earth Asteroid Tracking
NEO	Near-Earth object (or orbit)
NRCSD	NanoRacks Cubesat Deployer
NSS	National Space Society
OTA	Other Transaction Authority
PA	Public address
PA	Product assurance
PAM-D	Payload Assist Module
PDR	Preliminary Design Review
PGM	Platinum-group metals
PSLV	Polar-Orbiting Satellite Launch Vehicle
PTP	Point-to-point
PTS	Part-time Scientists (GLXP team)
QC	Quality control
R & D	Research and development
RESOLVE	Regolith and Environment Science, Oxygen and Lunar Volatiles Extraction
RFI	Request for information
RFP	Request for proposals
RFQ	Request for quotation
RIMS	Regional Input–Output Modeling System
RLV	Re-usable Launch Vehicle
RPM	Resource Prospector Mission
RSGS	Robotic Servicing of GEO Satellites
SABRE	Synergetic Air-Breathing Rocket Engine
SCSGi	Space Commercial Services Global Information
SERT	Space Solar Power Exploratory Research and Technology
SLI	Space Launch Initiative
SLS	Space Launch System

SNC	Sierra Nevada Corporation
SOW	Statement of Work
SpaceX	Space Exploration Technologies, Inc.
Spysat	Military Earth Observation Satellite
SS/L	Space Systems Loral
SSP	Space-based solar power
SST	Surrey Satellite Technology
START	Strategic Arms Reduction Treaty
STS	Space Transportation System (i.e., Space Shuttle)
TRB	Tender Review Board
t/Space	Transformational Space Inc.
TT&C	Telecommunications, tracking, and command
UAE	United Arab Emirates
UDMH	Unsymmetrical dimethylhydrazine
UN	United Nations
USSLCA	United States Space Launch Competitiveness Act
USSB	United States Satellite Broadcasting
VG	Virgin Galactic
VSAT	Very Small Aperture Terminal
VSE	Vision for Space Exploration
XS-1	Experimental Spaceplane 1

CHAPTER 1

Introduction

Ad Astra per Negotium—by Business to the Stars! That is my motto, and has been for half a century, since I first started working in the space program. In this book, I shall expand on that sentiment. Commercial business can turn around space endeavors from large outgoings paid from taxes, to a source of net income to the economy. I made my living out of this business—initially in the UK doing launcher and satcom work, then in the US helping build the new space tourism sector. In fact, I am still involved—now pushing the far-future applications of commercial space exploration. This book pulls it all together.

"No bucks: no Buck Rogers!" was a phrase dating back to the Project Mercury era in the US space program, around about 1960, and Tom Wolfe famously used it in his book, later to become a movie, "The Right Stuff". At that time, the intent was to convey the notion that space development and exploration were exceedingly expensive, and therefore in the US needed the backing of Congress to ensure that the necessary budgets were in place. That in turn implied the necessity for all involved in the space program to take time to keep the public and their representatives informed about plans and objectives. Again, back then, the government was the only source of funding for space activities. We shall see, in Section I, the significant price tag for that approach. In this book, we use the phrase differently, as a way of explaining why it was necessary to create the commercial space businesses. Simply put—it was not sustainable to spend government money the way it had been done in the 1960s in support of space development. Governments had indeed successfully funded the initial surge of space activities, or one could say provided the development finance, for the industry which was to emerge. However, the industries which emerged would thereafter have to be revenue-generating and self-sustaining. Thus began the never-ending search for the "killer app"—the commercial application of space which would bring the next surge of revenues to space businesses. Beyond a certain base level of government funding, which in the US was reduced to only one-tenth of what it had formerly been, it would be about supply and demand, and competitive pricing for services, just as is the case for traditional terrestrial businesses. In Section II, we shall observe how these traditional commercial space businesses emerged, how by working at reducing the costs they had become profitable ventures, and how to some degree they had matured through the remainder of the 20th century, and the first decade of the

21st century. A kind of plateau had by then been reached, where it was harder to find growth opportunities via these traditional commercial space businesses (mostly telecommunications and broadcasting). Something needed to change.

What could be the agent of change? What would be the new "killer app"? As we look forwards into the 21st century, we turn again to Buck Rogers for our inspiration. Buck Rogers was a fictional character appearing in magazines, newspaper strip cartoons, TV shows and movies, starting in the 1930s. Long before the word "astronaut" had been invented, Buck was wearing a glass bubble space helmet and a personalized flaming jet pack. This very idea of personal space travel, it emerges, opens up new growth markets for commercial space, and the concept of "New Space". These personal spaceflight business realities and opportunities are discussed in Section III, where we see that space tourism is a key transformative and enabling business. This section treats the emerging space tourism ventures as a transition step between the more traditional commercial space businesses, and those more speculative future ventures covered in the book's last section. Other elements of the changes brought about under this "New Space" transition environment are as simple, and yet as powerful an idea, as a switch to a different form of procurement process for space-related goods and services, and the continuing push towards re-usability.

Section IV describes a future series of business opportunities which are related to commercial space exploration. Just think about that. That very phrase "commercial space exploration" would have been an oxymoron only a few years ago. Some people think it still is. Surely it is governments who carry out space exploration, isn't it? We shall see how this new phase is already underway, and how it turns out that the efforts and motivations of entrepreneurial commercial space businesses are essential to ongoing progress, and to the consolidation of the exploration gains of the early space program.

This, then, is our task. We intend to take a journey together from the very beginning of the space program right up to the present day and onwards for several decades, noting the building blocks of the developing commercial space businesses throughout. I sometimes still find it astonishing that an entire field of endeavor, as important to the future of mankind as the space program, has all taken place within living memory. Maybe you recall, as I do, listening to the "beep beep beep ..." on the radio when Sputnik 1 was launched by the then Soviet Union in 1957, as well as the excitement and astonishment of hearing Yuri Gagarin speaking in Russian from space in 1961. Or maybe you heard about it from your grandparents! Starting with that early introduction, and because of the emergence of a global commercial space industry, I have been able to become involved in many of the developments of space business recounted in this book. This is a book about a global $247 billion business—how it got started, and where it is headed—and a note on a few of my own contributions along the way.

Although you will find lots of real information in this book, it is not written as an academic treatise. You will soon note that I do not shy away from value judgements. I am a firm believer in the benefits of commercial space transporta-

tion, exploration, resources and settlement in guaranteeing the long-term future of humankind. The tale of the initial creation of the business of commercial space is, by definition, about change. The future steps from today onwards (recounted in Section IV) are about change. We need to embrace it—even if initially it may in part make us feel uncomfortable. The very idea of mining asteroids, for example, raises many questions, yet it is due to the determined efforts of the early proponents of the space program that we can even consider it. We are at the beginning of an era when we can start to use the resources of the Solar System to augment those that exist on the Earth. So, I invite you to come with me as we retrace those early steps, and then change our focus to look forward to the enormous future potential for commercial space businesses.

Now, a note on scale. The development of space, whether for governmental or commercial purposes, always requires work related to both space and ground segments. This terminology refers to, on the one hand the spacecraft and the launch vehicles that get them into space, and on the other hand the terrestrial infrastructure (e.g., ground tracking stations) needed to support these operations. With the emergence of commercial space business into some mass market areas (such as GPS tracking units in vehicles) the scale of the ground segment can even exceed that of the space segment. The global commercial space business, by the end of 2015, reached $247 billion in revenues, a value which however is still not significant amongst other industry sectors within the total global economy of $78,000 billion. This indicates that there is still considerable opportunity for growth. This sector, one which relies on a highly educated workforce, has become an important part of our economic base, and will need to continue to be innovative as it pursues an effective growth strategy. It is the purpose of this book to provide, in part, a roadmap to assist in that process, whilst simultaneously recording the developments to date. For consistency, I have chosen to use US dollars and CGS units (e.g., km and kg). All of the data is consistent with the full year of 2015, and all the commentary reflects the world at end of June, 2016—exactly 50 years since I began my work in this business.

I have been lucky to have enjoyed a professional life in an industry which did not even exist until after I became a teenager, and so I am here recording some of the insights from these experiences to hopefully help in future developments. Having had the opportunity to meet several of the astronauts who risked their lives to walk on the Moon, I feel some sense of obligation to keep this particular line of developmental thought alive. Walking on the Moon was a graphic assertion of the capability of mankind to at last leave the Earth and explore further, and use the wealth of extra-terrestrial resources to improve life on this planet. In this book, we show how commercial space business has done its part thus far, and how it will continue to do so in the future; how much the business has been worth so far, and what its future prospects might be. You will also find some glimpses and insights into those real billion-dollar negotiations in which I took part—information on commercial space activities that is generally not otherwise available in the public domain. I include it for the

record, and because I suspect you will find it fascinating—and sometimes fun! In this book I am passing on information, data, procedures, sources and a sampling of 50 years of lessons learned.

Finally, a note on the illustrations which are very important to the unfolding of this story. They have been selected wherever possible to give some new insight. Many of them have not previously been published, and often they illustrate some personal connection for me that is described in the text. A good example is the wonderful painting by Phil Smith with which we end this introduction. In it, in a vast sweep of the imagination, we see the emergence of the entire commercial space business, starting with the first launch vehicles and satellites, then taking in the introduction of space tourism, moving on towards commercial space stations, asteroid mining, commercial space exploration and space settlement. For very good reasons, Phil calls this painting "Ascent".

Figure 1.1. The majestic sweep of the range of commercial space businesses, captured in this image, (titled "Ascent") shows, from left to right commercial launch and satellite businesses, space tourism businesses, commercial space stations and space exploration, asteroid mining and ultimately settlement.

(Credit: Phil Smith/author's private collection—acrylic on masonite panel, 58 cm × 28 cm)

SECTION I

Military and Governmental Beginnings

''Don't tell me that man doesn't belong out there. Man belongs wherever he wants to go—and he'll do plenty well when he gets there.''

Wernher von Braun, *Time Magazine*, February 17, 1958

CHAPTER 2

First there was the military

This section establishes the base on which the subsequent commercial development of space could be founded. We therefore need to go back to the very beginnings. The Second World War (1939–1945) ended with large swathes of Europe having been obliterated by the colossal bombardment of modern weaponry. This applied to the damage inflicted by ground troops, of course, but also to weapons delivered from the air. Germany bombarded London and other centers of population in Britain, and the same was true of the British and American air forces, who delivered more and more rounds of munitions onto the German cities and centers of production. Much of Russia, France, Belgium, Holland and Italy had been reduced to rubble by the ground battles which took place on their territory. Of course, the same can be said of the Pacific battlegrounds. Afterwards, the victors effectively divided the world politically into East and West, representing two different world views—Moscow representing the Soviet view of a communist doctrine, and Washington becoming the focal point of the western capitalist ideology. This set the stage for an era of mutual distrust and fear known as the Cold War (1945–1991).

A major reason for the fear was that during the Second World War, two extraordinary technologies had emerged from the conflict. One was the long-distance rocket, developed in Germany, and the other was atomic energy and specifically the A-bomb, developed initially in the US, but followed soon afterwards by a succession of "atomic powers" including initially the Soviet Union, the UK and France. The concern was that by combining these two technologies, world dominance would be achieved, possibly at the cost of elimination of a significant proportion of humanity. Of particular concern to the leadership and the population in the US was the recognition that the territory and cities of the continental US would not be immune from attack as they had been (apart from the bombing of the Pearl Harbor naval base) during World War 2. Although, of course, both technologies (rockets and atomic energy) had significant upside potential for improving life on Earth, it was the fear of military use which dominated the Cold War period. For good reason. The Second World War had ended when the US demonstrated the immense destructive power when atomic energy was released in single bombs over each of the cities of Hiroshima and Nagasaki in Japan, which obliterated much of their buildings and population. Therefore, during the 1950s and 1960s it was

required in US schools for children to undergo drills aimed at avoiding some of the damage from a potential nuclear attack. Although we may well wonder, in retrospect, whether getting away from windows and hiding under desks would have, in the event of such an attack, been a very effective tactic, nevertheless it does set the stage for the emergence of the space program, its military nature and the reason the American public supported the associated expenditures. It was seen as an existential crisis.

It could be argued that there were two starting points for the emergence of rocketry in the US. A great deal of experimental work was conducted by Dr. Robert Goddard, starting in 1926 and continuing in the period leading up to World War 2. However, this did not lead to the emergence of any military rockets. The real driver in the US was Dr. Wernher Von Braun, the leading German rocket engineer, who was brought with a hundred of his team to the US after the war, and continued thenceforth to develop practical rockets for the US Army. Other members from the German rocketeers were absorbed into the post-War Soviet rocket teams.

Von Braun had been the developer of the V2 rocket (Figure 2.1), about 3,000 of which had been dispatched from Germany aimed at Allied cities during the final stages of the War. He had learned his trade by launching those rockets mostly at London. Even today, all these years later, it is hard to get rocket launching experience in such massive quantities. Incidentally, I was a volunteer docent guide at the National Air and Space Museum (NASM) of the Smithsonian Institution in Washington, DC, and so I could regularly revisit the old artifacts. The particular example of the V2 at the NASM is painted in the colors that were used during the post-War era when von Braun's team was launching recovered examples over the White Sands desert of New Mexico, so that the US Army could also develop the necessary practical operational skills. Cameras on the ground could easily track the orientation of the vehicles through this paint scheme if, and when, they went off course or otherwise misbehaved. Von Braun then upgraded the V2 to become the Redstone and Jupiter class of tactical missiles—which then would subsequently have an important part to play as an early satellite launcher. However, the military needed something with a much longer range and payload capacity in order to deliver nuclear warheads over an intercontinental distance. Thus were born the ICBMs—the Intercontinental Ballistic Missiles. The Thor, Atlas and Titan ICBMs were developed, manufactured in quantities, and equipped with nuclear warheads as the US main operational components of the "Mutual Assured Destruction" (MAD) strategy that prevailed throughout the Cold War. Fortunately none were fired except as development and training rounds (minus their warheads!). Figure 2.2 shows an Atlas ICBM on a transporter. Again, like the Redstone, we shall see that this military weapon would have a key role to play later in a non-military capacity. Vast numbers of Minutemen missiles were also deployed in silos, "at the ready", during this Cold War period, and would later find a more convivial use in commercial space applications.

Of course, it was not just the US who were developing ICBMs during the

Figure 2.1. The beginnings of military rocketry—the V2 at the National Air and Space Museum (NASM) of the Smithsonian Institution, in Washington, DC.

(Credit: Author)

Cold War. The Soviet Union had been developing its own means of launching nuclear payloads across the oceans. In some ways, the technological base in Russia at the time was behind that of the US, although it was not realized at the time in the West. This meant that the payloads developed in Russia were much bigger and heavier than those built in the US. Consequently, the Soviets had to design and build launchers with a much bigger payload capacity. Figure 2.3 demonstrates the Russian response to this challenge.

In Figure 2.4, we see a Red Square May Day parade from that era (around 1963), which as you can imagine served only to fuel Western fears when shown on television. The parades seemed to go on for hours against a soundscape of martial music, with one transporter after another bringing ever larger missiles onto the ''stage'' with the backdrop of the Moscow Kremlin walls.