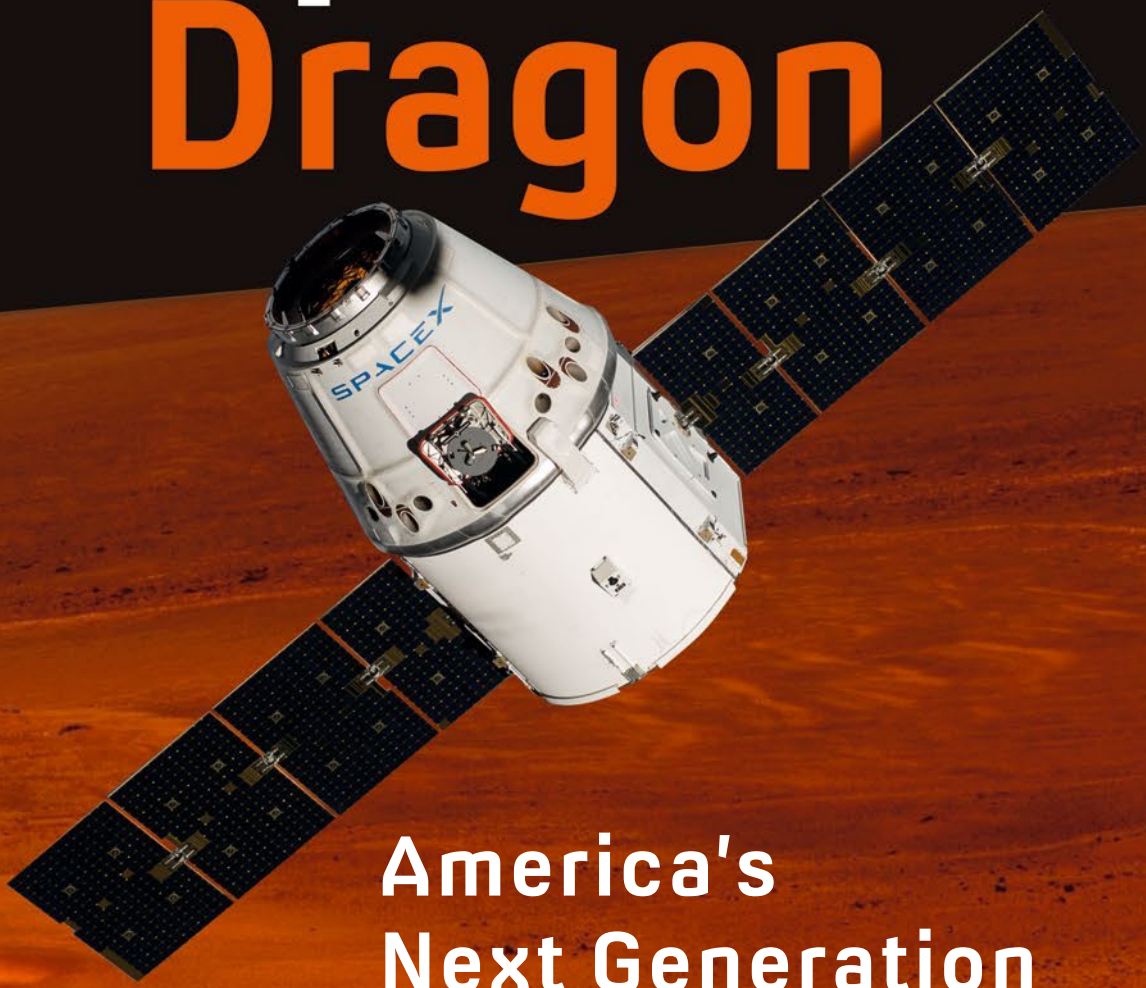
ERIK SEEDHOUSE

SpaceX's Dragon



America's Next Generation Spacecraft

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SpaceX's Dragon: America's Next Generation Spacecraft

Erik Seedhouse

SpaceX's Dragon: America's Next Generation Spacecraft

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About the author

Erik Seedhouse is a Norwegian-Canadian suborbital astronaut whose life-long ambition is to work in space. After completing his first degree in Sports Science, the author joined the legendary 2nd Battalion the Parachute Regiment. During his time in the "Para's", Erik spent six months in Belize, where he was trained in the art of jungle warfare. Later, he spent several months learning the intricacies of desert warfare on the Akamas Range in Cyprus. He made more than 30 jumps from a Hercules C130 aircraft, performed more than 200 abseils from a helicopter, and fired more light anti-tank weapons than he cares to remember!

Upon returning to the comparatively mundane world of academia, the author embarked upon a master's degree in Medical Science. He supported his studies by winning prize money in 100-kilometer running races. After placing third in the World 100km Championships in 1992 and setting the North American 100-kilometer record, Erik turned to ultra-distance triathlon, winning the World Endurance Triathlon Championships in 1995 and 1996. For good measure, he also won the inaugural World Double Ironman Championships in 1995 and the infamous Decatriathlon – an event requiring competitors to swim 38 kilometers, cycle 1,800 kilometers, and run 422 kilometers. Non-stop!

In 1996, Erik pursued his PhD at the German Space Agency's Institute for Space Medicine. While conducting his PhD studies, he found time to win Ultraman Hawai'i and the European Ultraman Championships as well as completing the Race Across America bike race. Due to his success as the world's leading ultra-distance triathlete, Erik was featured in dozens of magazine and television interviews. In 1997, *GQ* magazine nominated him as the "Fittest Man in the World".

In 1999, Erik decided it was time to get a real job. He retired from being a professional triathlete and took a research job at Vancouver's Simon Fraser University. In 2005, the author worked as an astronaut training consultant for Bigelow Aerospace and wrote *Tourists in Space*, a training manual for spaceflight participants. In 2009, he was one of the final 30 candidates in the Canadian Space Agency's Astronaut Recruitment Campaign. Erik works as an astronaut instructor, professional speaker, triathlon coach, and author. Between 2008 and 2013, he served as director of Canada's manned centrifuge and hypobaric operations.

In addition to being a certified suborbital scientist-astronaut, triathlete, centrifuge operator and director, pilot, and author, Erik is an avid mountaineer and is currently pursuing his goal of climbing the Seven Summits. *SpaceX's Dragon: America's Next-Generation Spacecraft* is his nineteenth book. When not writing and training astronauts, he spends as much time as possible in Kona on the Big Island of Hawai'i and in Sandefjord, Norway. Erik is based on Florida's Space Coast and is owned by his rambunctious cat, Lava.

Acronyms

AAU	Animal Access Unit
ACBM	Active Common Berthing Mechanism
AGPS	Assisted Global Positioning System
ALT	Approach and Landing Test
APAS	Androgynous Peripheral Attach System
ARC	Ames Research Center
ASDS	Autonomous Spaceport Drone Ship
ASGSR	American Society for Gravitational and Space Research
ATV	Automated Transfer Vehicle
BEAM	Bigelow Expandable Activity Module
BFR	Big Falcon Rocket
BTNR	Bimodal Thermal Nuclear Rocket
CAL	Cold Atom Lab
CATS	Cloud Aerosol Transport System
CBM	Common Berthing Mechanism
CBR	Certification Baseline Review
CCDev	Commercial Crew Development
CCiCap	Commercial Crew Capability
CCP	Commercial Crew Program
CCtCap	Commercial Crew Transportation Capability
CDR	Critical Design Review
CFD	Computational Fluid Dynamics
COTS	Commercial Orbital Transportation System
CPR	Certification Products Contract
CRS	Commercial Resupply Services
CSA	Canadian Space Agency
CST	Crew Transportation System
CUCU	Commercial UHF Communications Unit
DAV	Descent Assist Vehicle

DDTE	Design, Development, Test, and Evaluation
DRM	Design Reference Mission
EDL	Entry, Descent and Landing
EDS	Emergency Detection System
EOTP	Enhanced ORU Temporary Platform
ERV	Earth Return Vehicle
ETA	Experimental Test Article
FAA	Federal Aviation Administration
FAR	Federal Acquisitions Regulations
FDM	Free Drift Mode
FOR	Flight Operations Review
FRR	Flight Readiness Review
FTA	Flight Test Article
FTS	Flight Termination System
GTO	Geostationary Transfer Orbit
HDEV	High Definition Earth Viewing
HRSI	High-temperature Reusable Surface Insulation
HTV	H-I Transfer Vehicle
ICBM	Intercontinental Ballistic Missile
IRVE	Inflatable Re-entry Vehicle Experiment
IMU	Inertial Measurement Unit
IMMT	ISS Mission Management Team
ISS	International Space Station
JRMS	TEM Remote Manipulating System
KOS	Keep Out Sphere
LAS	Launch Abort System
LCC	Launch Commit Criteria
LEE	Latching End Effector
LEO	Low Earth Orbit
LIDS	Low Impact Docking System
LRT	Launch Readiness Test
MAV	Mars Ascent Vehicle
MCT	Mars Colonial Transporter
MDM	Multiplexer Demultiplexer
MERLIN	Microgravity Experiment Research Locker/INcubator
MLG	Main Landing Gear
MMOD	Micrometeoroid Orbital Debris
MOI	Mars Orbit Insertion
MSL	Mars Science Lander
MPCV	Multi Purpose Crew Vehicle
MTV	Mars Transit Vehicle
NDS	NASA Docking System
NIAC	NASA Institute for Advanced Concepts
NLG	Nose Landing Gear
NSPIRES	NASA Solicitation and Proposal Integrated Review and Evaluation System

NTR	Nuclear Thermal Rocket
OMAS	Orbital Maneuvering and Attitude System
OPALS	Optical Payload for Lasercomm Science
OPF	Orbiter Processing Facility
OV	Orbital Vehicle
PCM	Post Certification Mission
PDR	Preliminary Design Review
PDT	Propulsive Descent Technologies
PICA	Phenolic Impregnated Carbon Ablator
RAD	Radiation Assessment Detector
RCS	Reaction Control System
RSV	Respiratory Syncytial Virus
RTLS	Return To Launch Site
RWS	Robotic Work Station
SAA	Space Act Agreement
SAR	Search and Rescue
SCA	Shuttle Carrier Aircraft
SEI	Space Exploration Initiative
SIGI	Space Integrated GPS/INS
SLC	Space Launch Complex
SLS	Space Launch System
SORR	Stage Operations Readiness Review
SPDM	Special Purpose Dexterous Manipulator
SQU	Space Qualification Unit
SRP	Supersonic Retro-Propulsion
SRR	System Requirements Review
SSIKLOPS	Space Station Integrated Kinetic Launcher for Orbital Payload Systems
SSRMS	Space Station Remote Manipulator System
STP	Supersonic Transition Problem
TDRS	Tracking Data and Relay Satellite
TEI	Trans-Earth Insertion
TIM	Technical Interchange Meeting
TMI	Trans-Mars Injection
TPS	Thermal Protection System
VSE	Vision for Space Exploration
VTVL	Vertical Take-off Vertical Landing
WDR	Wet Dress Rehearsal
ZCG-FU	Zeolite Crystal Growth Furnace Unit

Foreword

In May 2014, SpaceX CEO, Elon Musk, pulled back the curtain on Dragon V2, the spaceship that his commercial spaceflight company hopes will carry NASA astronauts to the International Space Station (ISS) as soon as 2017. The unveiling of the Dragon V2 couldn't have come at a better time. Just a couple of weeks earlier, Russia's deputy prime minister vowed to bar NASA from hitching rides to the ISS aboard Russian Soyuz spacecraft in retaliation for Western sanctions imposed on Russia in response to the Ukraine crisis.

The fortuitous timing – together with Dragon V2's sleek design – will make the futuristic spacecraft a very attractive option for NASA, which is also considering designs by Boeing and Sierra Nevada. But more important to SpaceX is the advance towards the core company objective of reusability. Dragon V2, which was unveiled just weeks after SpaceX demonstrated technologies key to developing a reusable first rocket stage, can be retrieved, refurbished, *and* re-launched. It's a concept with the potential to completely revolutionize the economics of a spaceflight industry where equipment costing hundreds of millions of dollars is often discarded after a single use. With an egg-like shape, soft-white exterior, and SpaceX's name and stylish blue dragon logo emblazoned on its surface, the Dragon V2 spacecraft is much more modern than the Apollo capsules. Inside, the capsule is elegant but sparse, with seven couches facing upward beneath a large, flat-panel display, which serves as the craft's only controls.

SpaceX's Dragon: America's Next-Generation Spacecraft describes the extraordinary feats of engineering and human achievement that have placed this extraordinary spacecraft at the forefront of the launch industry and positioned it as the most likely candidate for transporting humans not only to the ISS, but also to Mars.

1

SpaceX

Elon Musk. Credit: SpaceX

ONE MAN'S MISSION

In 2015, Elon Musk doesn't need to be introduced. Like Wernher von Braun, Musk is a legend in his own lifetime, and deservedly so. A billionaire many times over thanks in part to PayPal and Tesla, Musk is a transformational technologist who has plans to retire on Mars. Why? Not to inspire or to make money. Musk's aim is nothing less than to make us

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a multi-planet species. For Musk, colonizing Mars is extinction insurance, and he wants to send a manned mission sooner rather than later. And cheaper. As he points out in interviews, the Curiosity rover that is ambling around on Mars cost more than US$3 billion. Musk reckons, for that money, we should be sending humans and he has a plan to do exactly that. Shortly before SpaceX was founded, Musk remembers a late night spent searching for a NASA website that outlined the plans for a manned mission to Mars. It was 2001 and the Shuttles were still flying at a flight rate that was sufficient to persuade the public that manned spaceflight was still a serious concern. Now, in 2015, with the Shuttle a rapidly receding memory, the notion that manned spaceflight is a vibrant arena is pure delusion. In 2015, American, European, and Canadian astronauts climb on board the Soyuz for their ride to the International Space Station (ISS), and there aren't many people who want to watch spacefarers climb into an aged space vehicle to a destination that is 1,000 times closer to Earth than the Moon. Mars? That isn't even on most people's radar. But many people have accepted this as the norm. A manned mission to Mars? That won't happen for decades, especially if we rely on a government to get us there. A few decades ago, following the Moon landing, the thinking was different. The Apollo program would springboard us to Mars and visits to the Moon and the Red Planet would become routine. Permanent bases would be built on the lunar surface and, after settling on Mars (Figure 1.1), we start shooting for the outer planets. Nothing was impossible. Except that it was.

Back in 2001, when Musk (see sidebar) discovered there were no manned Mars missions on the books, he reckoned the US was no longer interested in manned space exploration. But two years later, the *Columbia* accident proved otherwise. Still, the budget for NASA had been atrophying at an alarming rate since the mid-1960s, when the agency received 4.4% of the federal budget. In the 2000s and 2010s, the NASA budget was just 0.5% of the total US budget, which is part of the reason Musk couldn't find any information about a manned Mars mission. Appalled at the lack of progress, Musk began dreaming up a manned Mars mission of his own, but first he needed to build a rocket company, and so SpaceX was born. The story of this visionary company is told in *SpaceX*: *Making Commercial Spaceflight a Reality*, which was written by this author and published in 2013, so what follows is a brief overview of how Musk made his company the success that it is today.

1.1 Musk's goal is to colonize Mars. Credit: NASA

Elon Musk

Elon Musk is a genius on a mission. Those who follow the goings on in the world of commercial spaceflight will know all about the Falcon 9 and Dragon, and may assume Musk's primary goal is to ferry astronauts to the ISS, because this is the story the media seem to focus on. But Musk's vision extends far beyond low Earth orbit (LEO). He wants to transport people to Mars. Thousands of them. And a big part of that plan is SpaceX, Musk's rocket company that is based in El Segundo, California. SpaceX's hangar is a hangar like any other, except SpaceX's place of work happens to be the site of a revolution in the way spaceflight is conducted. At the time of writing, SpaceX had been around for just 13 short years but, in that time frame, it has achieved more than most national space programs. It has developed its own rocket engines, launcher, *and* spacecraft, and is now poised to deliver astronauts to the ISS. With an employee roster of little more than 1,000, SpaceX has been created thanks to one man and one man only: Elon Musk.

Having bought his first computer when he was 10, Musk, who lived in South Africa as a youngster, learned how to write commercial software and put that knowledge to good use by writing a space – what else? – game called *Blastar*. He was only 12 years old. At 17, he traveled to Canada before beginning life as a student at the University of Pennsylvania. He gained one degree in physics and one in economics, and then headed to Stanford in 1995, where he spent just 48 hours before deciding it would be more exciting to start an internet company. And so Zip2 was born. Zip2 produced publishing software. Musk sold the company in 1999 for a cool US$300 million and then founded X.com, which eventually became PayPal. Perhaps you've heard of it? Musk sold PayPay to eBay for US$1.5 billion in 2002.

For most people, this would be enough. Sit back, head for Tahiti, and soak up your success in the sunshine. But not Musk. Becoming a billionaire was just the beginning because, besides being extremely rich, Musk is also very, *very* single-minded. And one of his goals was to make space affordable and along the way send people to Mars. Never mind that these goals have eluded governments for decades. Musk reckoned the government's way of doing business in space was inefficient in the extreme and he decided he would do it more affordably. And that's what he did. His rockets place cargo into space at a fraction of the cost of his rivals and his company's development of Dragon has been lightning fast.

Inevitably, all this success has cast Musk in the media spotlight. Not surprising really, given that Musk was the inspiration for *Iron Man*'s Tony Stark (Musk made a cameo appearance in *Iron Man 2*), but Musk would rather spend his time dreaming up how he can get us to Mars than answering questions for a magazine. After all, this is a man who spends 100 hours a week at work and logging so many hours means there just isn't time to indulge the media or spend time telling people about his private life (Musk has neither a Facebook nor a Twitter account). While he is a businessman and a celebrity, the word that most accurately defines Musk is "dreamer." He didn't create SpaceX to make another tonne of money. He created it as a stepping stone to help humanity on their way to Mars. He reckons we can get there in 20 years.