



1
00:00:01,200 --> 00:00:04,900
[musical tones]
[electronic sounds of data]

2
00:00:16,466 --> 00:00:18,000
- Thank you. Thank you.
Well, welcome.

3
00:00:18,000 --> 00:00:19,500
What a great turnout.

4
00:00:19,500 --> 00:00:23,566
And welcome to the
2015 NASA Ames Summer Series.

5
00:00:23,566 --> 00:00:26,200
And I have the great honor
and pleasure

6
00:00:26,200 --> 00:00:29,466
of introducing one
of our two distinguished guests.

7
00:00:29,466 --> 00:00:32,033
I'd like to introduce
Dr. Jim Green,

8
00:00:32,033 --> 00:00:35,733
who is our director
of planetary sciences for NASA,

9
00:00:35,733 --> 00:00:38,666
and he will do the introduction
of our guest speaker.

10
00:00:38,666 --> 00:00:40,000
Welcome again.

11
00:00:40,000 --> 00:00:43,000

[applause]

12

00:00:45,200 --> 00:00:47,100

- Thank you very much, Eugene.

13

00:00:47,100 --> 00:00:51,500

You know, science fiction stories allow us to dream big

14

00:00:51,500 --> 00:00:53,733

and imagine the impossible.

15

00:00:53,733 --> 00:00:56,766

These stories become, in many cases--

16

00:00:56,766 --> 00:01:00,833

that are classic stories-- become embedded in our minds

17

00:01:00,833 --> 00:01:04,500

and the way we think and the way we work in the future

18

00:01:04,500 --> 00:01:07,166

and in our society.

19

00:01:07,166 --> 00:01:10,700

The stories sometimes allow us to be creative

20

00:01:10,700 --> 00:01:13,133

and invent a new future.

21

00:01:13,133 --> 00:01:16,666

Science fiction is a critical element

22

00:01:16,666 --> 00:01:20,100

of the way we think
and the way we act.

23

00:01:20,100 --> 00:01:22,066
Today's colloquium,

24

00:01:22,066 --> 00:01:26,066
"The Martian":
How Science Drove the Plot,"

25

00:01:26,066 --> 00:01:29,100
will be presented by Andy Weir.

26

00:01:29,100 --> 00:01:31,333
You know, Andy was hired
as a programmer

27

00:01:31,333 --> 00:01:34,733
for a national laboratory
at the age of 15

28

00:01:34,733 --> 00:01:38,766
and had been working as a
software engineer ever since.

29

00:01:38,766 --> 00:01:42,900
He is also
a lifelong space nerd

30

00:01:42,900 --> 00:01:44,566
like many of us

31

00:01:44,566 --> 00:01:46,733
and is a devoted hobbyist

32

00:01:46,733 --> 00:01:49,233
on subjects
such as relativistic physics,

33

00:01:49,233 --> 00:01:50,800
orbital mechanics,

34

00:01:50,800 --> 00:01:53,800
and the history
of manned space flight.

35

00:01:53,800 --> 00:01:58,166
"The Martian"
is Andy's first published novel.

36

00:01:58,166 --> 00:02:01,966
He originally
self-published it in 2011

37

00:02:01,966 --> 00:02:05,500
and rereleased it in 2014.

38

00:02:05,500 --> 00:02:08,133
Now, as many know,
it's actually been picked up

39

00:02:08,133 --> 00:02:12,700
by 20th Century Fox as a movie.

40

00:02:12,700 --> 00:02:15,166
Ridley Scott is the producer.

41

00:02:15,166 --> 00:02:19,766
If you've seen the trailers,
that is a movie I want to see.

42

00:02:19,766 --> 00:02:21,833
But of course
I want to tell you,

43

00:02:21,833 --> 00:02:25,866
"The Martian" should be
required reading for NASA.

44

00:02:25,866 --> 00:02:29,500

Today Andy will describe
how science drove the plot,

45

00:02:29,500 --> 00:02:31,300

illuminating the connectivity

46

00:02:31,300 --> 00:02:34,400

between science fiction
and science fact.

47

00:02:34,400 --> 00:02:37,466

So let's give a round
of applause to Andy Weir.

48

00:02:37,466 --> 00:02:40,400

[applause]

49

00:02:40,400 --> 00:02:43,066

- Thank you.

50

00:02:43,066 --> 00:02:45,566

All right.

51

00:02:45,566 --> 00:02:47,233

Thank you.

52

00:02:47,233 --> 00:02:49,066

All right.

53

00:02:49,066 --> 00:02:50,466

Hello, everybody.

54

00:02:50,466 --> 00:02:53,433

Um, let me just find out
if my wandering mic is hot.

55

00:02:53,433 --> 00:02:54,433

Test, test.

56

00:02:54,433 --> 00:02:56,566

Oh, hey, there we go.

57

00:02:56,566 --> 00:03:00,066

Now I can pontificate
from anywhere.

58

00:03:00,066 --> 00:03:02,266

So I'm going to start
with a reading,

59

00:03:02,266 --> 00:03:05,733

and then I'm going to talk about
how science drove the plot,

60

00:03:05,733 --> 00:03:07,666

as promised.

61

00:03:07,666 --> 00:03:11,133

All right, so there's
a lot of profanity in this book,

62

00:03:11,133 --> 00:03:14,366

but a show of hands,
who's read it?

63

00:03:14,366 --> 00:03:16,466

Yeah, that's what I like
to see.

64

00:03:16,466 --> 00:03:19,100

Show of hands,
who's buying it today?

65

00:03:19,100 --> 00:03:21,400

Aw, see, now...

66

00:03:21,400 --> 00:03:24,366
[laughter]

67
00:03:24,366 --> 00:03:26,066
No.

68
00:03:26,066 --> 00:03:30,066
So I'm going to be substituting

69
00:03:30,066 --> 00:03:33,133
softer swear words

70
00:03:33,133 --> 00:03:34,900
for the profanities,

71
00:03:34,900 --> 00:03:38,266
so here we go.

72
00:03:38,266 --> 00:03:40,433
"Log entry: Sol 6.

73
00:03:40,433 --> 00:03:42,666
I'm pretty much 'screwed.'

74
00:03:42,666 --> 00:03:45,366
[laughter]

75
00:03:45,366 --> 00:03:48,500
That's my considered opinion--
screwed.

76
00:03:48,500 --> 00:03:51,766
Six days into what should be the
greatest two months of my life

77
00:03:51,766 --> 00:03:53,800
and it's turned
into a nightmare.

78

00:03:53,800 --> 00:03:55,366

I don't even know
who'll read this.

79

00:03:55,366 --> 00:03:57,566

I guess someone
will find it eventually,

80

00:03:57,566 --> 00:03:59,433

maybe 100 years from now.

81

00:03:59,433 --> 00:04:02,366

For the record,
I didn't die on Sol 6.

82

00:04:02,366 --> 00:04:04,333

Certainly the rest of the crew
thought I did,

83

00:04:04,333 --> 00:04:06,000

and I can't blame them.

84

00:04:06,000 --> 00:04:08,133

Maybe there'll be a day
of national mourning for me,

85

00:04:08,133 --> 00:04:09,733

and my Wikipedia page will say,

86

00:04:09,733 --> 00:04:13,066

'Mark Watney is the only human
being to have died on Mars.'

87

00:04:13,066 --> 00:04:16,466

And it'll be right, probably,
'cause I'll surely die here,

88

00:04:16,466 --> 00:04:19,733

just not on Sol 6

when everyone thinks I did.

89

00:04:19,733 --> 00:04:21,933

Let's see, where do I begin?

90

00:04:21,933 --> 00:04:23,500

The Ares Program--

91

00:04:23,500 --> 00:04:26,666

mankind reaching out to Mars
to send people to another planet

92

00:04:26,666 --> 00:04:29,866

for the very first time and
expand the horizons of humanity,

93

00:04:29,866 --> 00:04:31,833

blah, blah, blah.

94

00:04:31,833 --> 00:04:34,733

The Ares 1 crew did their
thing and came back heroes.

95

00:04:34,733 --> 00:04:37,933

They got the parades and fame
and love of the world.

96

00:04:37,933 --> 00:04:41,500

Ares 2 did the same thing
in a different location on Mars.

97

00:04:41,500 --> 00:04:43,600

They got a firm handshake
and a hot cup of coffee

98

00:04:43,600 --> 00:04:45,233

when they got home.

99

00:04:45,233 --> 00:04:48,100

Ares 3,
well, that was my mission.

100
00:04:48,100 --> 00:04:50,400
Okay, not mine, per se.

101
00:04:50,400 --> 00:04:52,100
Commander Lewis was in charge.

102
00:04:52,100 --> 00:04:54,200
I was just one of her crew.

103
00:04:54,200 --> 00:04:56,100
Actually, I was
the very lowest-ranked member

104
00:04:56,100 --> 00:04:57,500
of her crew.

105
00:04:57,500 --> 00:04:59,366
I would only be
'in command' of the mission

106
00:04:59,366 --> 00:05:01,233
if I were the only
remaining person.

107
00:05:01,233 --> 00:05:02,700
Hey, what do you know?
I'm in command.

108
00:05:02,700 --> 00:05:05,466
[laughter]

109
00:05:05,466 --> 00:05:07,166
I wonder if this log
will be recovered

110
00:05:07,166 --> 00:05:09,733

before the rest of the crew
die of old age.

111
00:05:09,733 --> 00:05:12,100
I presume they got
back to Earth all right.

112
00:05:12,100 --> 00:05:14,866
Guys, if you're reading this,
it wasn't your fault.

113
00:05:14,866 --> 00:05:16,200
You did what you had to do.

114
00:05:16,200 --> 00:05:18,933
In your position, I would have
done the same thing.

115
00:05:18,933 --> 00:05:21,666
I don't blame you,
and I'm glad you survived.

116
00:05:21,666 --> 00:05:24,366
I guess I should explain
how Mars missions work

117
00:05:24,366 --> 00:05:26,966
for any layman
who may be reading this.

118
00:05:26,966 --> 00:05:29,000
We got to Earth orbit
the normal way,

119
00:05:29,000 --> 00:05:30,966
through an ordinary ship
to Hermes.

120
00:05:30,966 --> 00:05:32,733
All the area's missions

use Hermes

121

00:05:32,733 --> 00:05:34,300
to get to and from Mars.

122

00:05:34,300 --> 00:05:36,400
It's really big,
and it cost a lot,

123

00:05:36,400 --> 00:05:38,033
so NASA only built one.

124

00:05:38,033 --> 00:05:42,166
Once we got to Hermes, four
additional unmanned missions

125

00:05:42,166 --> 00:05:45,966
brought us fuel and supplies
while we prepared for our trip.

126

00:05:45,966 --> 00:05:48,566
Once everything was a go,
we set out for Mars,

127

00:05:48,566 --> 00:05:50,133
but not very fast.

128

00:05:50,133 --> 00:05:52,366
Gone are the days
of heavy chemical fuel burns

129

00:05:52,366 --> 00:05:54,700
and trans-Mars injection orbits.

130

00:05:54,700 --> 00:05:57,700
Hermes is powered
by ion engines.

131

00:05:57,700 --> 00:06:00,300

They throw argon out the back
of the ship really fast

132

00:06:00,300 --> 00:06:02,566

to get a tiny amount
of acceleration.

133

00:06:02,566 --> 00:06:05,733

The thing is, it doesn't take
much reactant mass,

134

00:06:05,733 --> 00:06:08,500

so a little argon and a nuclear
reactor to power things

135

00:06:08,500 --> 00:06:11,466

let us accelerate constantly
the whole way there.

136

00:06:11,466 --> 00:06:13,433

You'd be amazed
at how fast you can get going

137

00:06:13,433 --> 00:06:16,566

with a tiny acceleration
over a long time.

138

00:06:16,566 --> 00:06:18,400

I could regale you with tales

139

00:06:18,400 --> 00:06:21,266

of how we had great fun
on the trip, but I won't.

140

00:06:21,266 --> 00:06:23,300

I don't feel like
reliving it right now.

141

00:06:23,300 --> 00:06:26,333

Suffice it to say, we got

to Mars 124 days later

142

00:06:26,333 --> 00:06:28,766
without strangling each other.

143

00:06:28,766 --> 00:06:32,200
From there, we took the MDV,
Mars Descent Vehicle,

144

00:06:32,200 --> 00:06:33,866
to the surface.

145

00:06:33,866 --> 00:06:35,800
The MDV is basically a big can

146

00:06:35,800 --> 00:06:38,666
with some light thrusters
and parachutes attached.

147

00:06:38,666 --> 00:06:41,633
Its sole purpose is to get
six humans from Mars' orbit

148

00:06:41,633 --> 00:06:44,500
to the surface
without killing any of them.

149

00:06:44,500 --> 00:06:47,200
And now we get to the real trick
of Mars exploration--

150

00:06:47,200 --> 00:06:50,533
having all your crap
there in advance.

151

00:06:50,533 --> 00:06:52,633
A total of 14 unmanned missions

152

00:06:52,633 --> 00:06:55,900

deposited everything we would
need for surface operations.

153

00:06:55,900 --> 00:06:58,033

They tried their best
to land all the supply vessels

154

00:06:58,033 --> 00:07:01,766

in the same general area
and did a reasonably good job.

155

00:07:01,766 --> 00:07:03,933

Supplies aren't nearly
so fragile as humans

156

00:07:03,933 --> 00:07:05,866

and can hit the ground
really hard,

157

00:07:05,866 --> 00:07:08,833

but they tend
to bounce around a lot.

158

00:07:08,833 --> 00:07:10,533

Naturally,
they didn't send us to Mars

159

00:07:10,533 --> 00:07:12,733

until they'd confirmed that
all the supplies had made it

160

00:07:12,733 --> 00:07:15,333

to the surface and their
containers weren't breached.

161

00:07:15,333 --> 00:07:17,800

Start to finish,
including supply missions,

162

00:07:17,800 --> 00:07:20,366

a Mars mission takes
about three years.

163
00:07:20,366 --> 00:07:23,333
In fact, there were Ares 3
supplies en route to Mars

164
00:07:23,333 --> 00:07:26,866
while the Ares 2 crew
were on their way home.

165
00:07:26,866 --> 00:07:29,800
The most important piece
of advance supplies, of course,

166
00:07:29,800 --> 00:07:32,666
was the MAV--
the Mars Ascent Vehicle.

167
00:07:32,666 --> 00:07:34,133
That's how we would
get back to Hermes

168
00:07:34,133 --> 00:07:36,500
after surface operations
were complete.

169
00:07:36,500 --> 00:07:38,233
The MAV was soft-landed,

170
00:07:38,233 --> 00:07:40,066
as opposed
to the balloon bounce-fest

171
00:07:40,066 --> 00:07:42,033
the other supplies had.

172
00:07:42,033 --> 00:07:44,900
Of course, it was in constant
communication with Houston,

173

00:07:44,900 --> 00:07:47,066

and if there had been
any problems with it,

174

00:07:47,066 --> 00:07:50,300

we would have passed by Mars and
gone home without ever landing.

175

00:07:50,300 --> 00:07:52,000

The MAV is pretty cool.

176

00:07:52,000 --> 00:07:54,100

Turns out, through a neat set
of chemical reactions

177

00:07:54,100 --> 00:07:55,733

with the Martian atmosphere,

178

00:07:55,733 --> 00:07:58,133

for every kilogram of hydrogen
you bring to Mars,

179

00:07:58,133 --> 00:08:00,566

you can make 13 kilograms
of fuel.

180

00:08:00,566 --> 00:08:02,300

It's a slow process, though.

181

00:08:02,300 --> 00:08:04,533

It takes 24 months
to fill the tank.

182

00:08:04,533 --> 00:08:06,900

That's why they sent it
long before we got here.

183

00:08:06,900 --> 00:08:08,700

You can imagine
how disappointed I was

184
00:08:08,700 --> 00:08:12,033
when I discovered
the MAV was gone.

185
00:08:12,033 --> 00:08:14,066
It was a ridiculous sequence
of events

186
00:08:14,066 --> 00:08:15,533
that led to me almost dying

187
00:08:15,533 --> 00:08:17,000
and an even more
ridiculous sequence

188
00:08:17,000 --> 00:08:18,633
that led to me surviving.

189
00:08:18,633 --> 00:08:20,900
The mission is designed
to handle sandstorm gusts

190
00:08:20,900 --> 00:08:23,700
up to 150 kilometers per hour.

191
00:08:23,700 --> 00:08:26,400
So Houston got understandably
nervous when we got whacked

192
00:08:26,400 --> 00:08:29,000
with 175-kilometer-per-hour
winds.

193
00:08:29,000 --> 00:08:30,633
We all got
in our flight space suits

194

00:08:30,633 --> 00:08:32,166

and huddled in the middle
of the Hab

195

00:08:32,166 --> 00:08:35,700

just in case it lost pressure,
but the Hab wasn't the problem.

196

00:08:35,700 --> 00:08:37,333

The MAV is a spaceship.

197

00:08:37,333 --> 00:08:39,300

It has a lot of delicate parts.

198

00:08:39,300 --> 00:08:41,533

It can put up with storms
to a certain extent,

199

00:08:41,533 --> 00:08:43,966

but it can't just get
sandblasted forever.

200

00:08:43,966 --> 00:08:46,400

After an hour and a half
of sustained wind,

201

00:08:46,400 --> 00:08:48,066

NASA gave the order to abort.

202

00:08:48,066 --> 00:08:50,000

Nobody wanted to stop
a month-long mission

203

00:08:50,000 --> 00:08:51,400

after only six days,

204

00:08:51,400 --> 00:08:53,166

but if the MAV took
anymore punishment,

205

00:08:53,166 --> 00:08:56,166
we'd all have gotten stranded
down there.

206

00:08:56,166 --> 00:08:59,666
We had to go out into the storm
to get from the Hab to the MAV.

207

00:08:59,666 --> 00:09:02,400
That was going to be risky,
but what choice did we have?

208

00:09:02,400 --> 00:09:04,933
Everyone made it but me.

209

00:09:04,933 --> 00:09:06,700
Our main communications dish,

210

00:09:06,700 --> 00:09:09,200
which relayed signals
from the Hab to Hermes,

211

00:09:09,200 --> 00:09:11,966
acted like a parachute,
getting torn from its foundation

212

00:09:11,966 --> 00:09:13,800
and carried along
with the torrent.

213

00:09:13,800 --> 00:09:15,066
Along the way,

214

00:09:15,066 --> 00:09:17,266
it crashed through
the reception antenna array.

215

00:09:17,266 --> 00:09:18,733

Then one of those
long, thin antennae

216
00:09:18,733 --> 00:09:20,800
slammed into me end-first.

217
00:09:20,800 --> 00:09:23,266
It tore through my suit
like a bullet through butter,

218
00:09:23,266 --> 00:09:26,866
and I felt the worst pain in my
life as it ripped open my side.

219
00:09:26,866 --> 00:09:29,100
I vaguely remember having
the wind knocked out of me,

220
00:09:29,100 --> 00:09:30,533
pulled out of me really,

221
00:09:30,533 --> 00:09:34,066
and my ears popping painfully as
the pressure of my suit escaped.

222
00:09:34,066 --> 00:09:35,333
The last thing I remember

223
00:09:35,333 --> 00:09:39,066
was seeing Johanssen hopelessly
reaching out toward me.

224
00:09:39,066 --> 00:09:41,366
I awoke to the oxygen alarm
in my suit--

225
00:09:41,366 --> 00:09:44,200
a steady, obnoxious beeping
that eventually roused me

226

00:09:44,200 --> 00:09:47,700

from a deep and profound desire
to just die.

227

00:09:47,700 --> 00:09:49,166

The storm had abated.

228

00:09:49,166 --> 00:09:51,933

I was facedown,
almost totally buried in sand.

229

00:09:51,933 --> 00:09:53,400

As I groggily came to,

230

00:09:53,400 --> 00:09:56,133

I wondered
why I wasn't more dead.

231

00:09:56,133 --> 00:09:57,566

The antenna had enough force

232

00:09:57,566 --> 00:09:59,566

to punch through the suit
and my side,

233

00:09:59,566 --> 00:10:01,500

but it had been stopped
by my pelvis,

234

00:10:01,500 --> 00:10:03,233

so there was only one hole
in the suit

235

00:10:03,233 --> 00:10:05,400

and a hole in me, of course.

236

00:10:05,400 --> 00:10:07,100

I'd been knocked back
quite a ways

237

00:10:07,100 --> 00:10:08,900
and rolled down a steep hill.

238

00:10:08,900 --> 00:10:10,600
Somehow, I landed facedown,

239

00:10:10,600 --> 00:10:13,033
which forced the antenna
to a strongly oblique angle

240

00:10:13,033 --> 00:10:15,766
that put a lot of torque
on the hole in my suit.

241

00:10:15,766 --> 00:10:17,633
It made a weak seal.

242

00:10:17,633 --> 00:10:20,066
Then the copious blood
from my wound

243

00:10:20,066 --> 00:10:21,900
trickled down toward the hole.

244

00:10:21,900 --> 00:10:23,900
As the blood reached
the site of the breach,

245

00:10:23,900 --> 00:10:25,400
the water in it
quickly evaporated

246

00:10:25,400 --> 00:10:27,066
from airflow and low pressure,

247

00:10:27,066 --> 00:10:29,266
leaving a gunky residue behind.

248

00:10:29,266 --> 00:10:32,333

More blood came in behind it
and was also reduced to gunk.

249

00:10:32,333 --> 00:10:34,733

Eventually, it sealed
the gaps around the hole

250

00:10:34,733 --> 00:10:35,900

and reduced the leak

251

00:10:35,900 --> 00:10:38,800

to something
the suit could counteract.

252

00:10:38,800 --> 00:10:40,933

The suit did its job admirably.

253

00:10:40,933 --> 00:10:43,800

Sensing the drop in pressure,
it constantly flooded itself

254

00:10:43,800 --> 00:10:46,600

with air from my nitrogen tank
to equalize.

255

00:10:46,600 --> 00:10:48,266

Once the leak
became manageable,

256

00:10:48,266 --> 00:10:50,000

it only had to trickle
new air in slowly

257

00:10:50,000 --> 00:10:51,733

to relieve the air lost.

258

00:10:51,733 --> 00:10:53,000

After a while,

259

00:10:53,000 --> 00:10:55,966
the CO2--carbon dioxide--
absorbers in the suit

260

00:10:55,966 --> 00:10:57,366
were expended.

261

00:10:57,366 --> 00:10:59,766
That's really the limiting
factor to life support--

262

00:10:59,766 --> 00:11:02,000
not the amount of oxygen
you can bring with you,

263

00:11:02,000 --> 00:11:04,200
but the amount of CO2
you can remove.

264

00:11:04,200 --> 00:11:06,500
In the Hab,
I had the oxygenator--

265

00:11:06,500 --> 00:11:09,066
a large piece of equipment
that breaks CO2 apart

266

00:11:09,066 --> 00:11:10,733
to give the oxygen back,

267

00:11:10,733 --> 00:11:13,333
but in the space suits,
they have to be portable,

268

00:11:13,333 --> 00:11:15,466
so they use a simple
chemical-absorption process

269

00:11:15,466 --> 00:11:17,100
with expendable filters.

270
00:11:17,100 --> 00:11:21,066
I'd been asleep long enough
that my filters were useless.

271
00:11:21,066 --> 00:11:23,766
The suit saw this problem
and moved into an emergency mode

272
00:11:23,766 --> 00:11:25,933
the engineers called
'bloodletting.'

273
00:11:25,933 --> 00:11:28,266
Having no way
to separate out the CO₂,

274
00:11:28,266 --> 00:11:31,100
the suit deliberately vented air
to the Martian atmosphere,

275
00:11:31,100 --> 00:11:32,800
then backfilled with nitrogen.

276
00:11:32,800 --> 00:11:34,466
Between the breach
and the bloodletting,

277
00:11:34,466 --> 00:11:36,433
it quickly ran out of nitrogen.

278
00:11:36,433 --> 00:11:38,833
All it had left
was my oxygen tank.

279
00:11:38,833 --> 00:11:41,366
So it did the only thing
it could to keep me alive--

280

00:11:41,366 --> 00:11:44,033

it started backfilling
with pure oxygen.

281

00:11:44,033 --> 00:11:46,200

I now risked dying
from oxygen toxicity,

282

00:11:46,200 --> 00:11:49,066

as the excessively high amount
of oxygen threatened to burn up

283

00:11:49,066 --> 00:11:51,100

my nervous system,
lungs, and eyes.

284

00:11:51,100 --> 00:11:53,800

An ironic death for someone
with a leaky space suit--

285

00:11:53,800 --> 00:11:55,800

too much oxygen.

286

00:11:55,800 --> 00:11:57,133

Every step of the way

287

00:11:57,133 --> 00:11:59,166

would have had beeping alarms,
alerts, and warnings,

288

00:11:59,166 --> 00:12:00,900

but it was
the high-oxygen warning

289

00:12:00,900 --> 00:12:02,833

that eventually woke me.

290

00:12:02,833 --> 00:12:06,166

The sheer volume of training for a space mission is astounding.

291

00:12:06,166 --> 00:12:07,266
I'd spent a week back on Earth

292

00:12:07,266 --> 00:12:09,733
practicing emergency
space suit drills.

293

00:12:09,733 --> 00:12:11,066
I knew what to do.

294

00:12:11,066 --> 00:12:12,833
Carefully reaching
to the side of my helmet,

295

00:12:12,833 --> 00:12:14,366
I got the breach kit.

296

00:12:14,366 --> 00:12:17,366
It's nothing more than a funnel
with a valve at the small end

297

00:12:17,366 --> 00:12:20,166
and an unbelievably sticky resin
on the wide end.

298

00:12:20,166 --> 00:12:21,800
The idea is,
you have the valve open

299

00:12:21,800 --> 00:12:24,000
and stick the wide end
over a hole.

300

00:12:24,000 --> 00:12:25,566
The air can escape
through the valve

301

00:12:25,566 --> 00:12:28,400

so it doesn't interfere with
the resin, making a good seal.

302

00:12:28,400 --> 00:12:31,200

Then you close the valve,
and you've sealed the breach.

303

00:12:31,200 --> 00:12:34,166

The tricky part was getting
the antenna out of the way.

304

00:12:34,166 --> 00:12:35,766

I pulled it out
as fast as I could,

305

00:12:35,766 --> 00:12:37,866

wincing as the sudden
pressure drop dizzied me

306

00:12:37,866 --> 00:12:40,833

and made the wound in my side
scream in agony.

307

00:12:40,833 --> 00:12:43,266

I got the breach kit
over the hole and sealed it.

308

00:12:43,266 --> 00:12:44,766

It held.

309

00:12:44,766 --> 00:12:48,133

The suit backfilled the missing
air with yet more oxygen.

310

00:12:48,133 --> 00:12:49,566

Checking my arm readouts,

311

00:12:49,566 --> 00:12:52,366

I saw the suit was now
85% oxygen.

312

00:12:52,366 --> 00:12:55,633

For reference,
Earth's atmosphere is about 21%.

313

00:12:55,633 --> 00:12:59,900

I'd be okay, so long as I didn't
spend too much time like that.

314

00:12:59,900 --> 00:13:02,466

I stumbled up the hill
and back toward the Hab.

315

00:13:02,466 --> 00:13:03,600

As I crested the rise,

316

00:13:03,600 --> 00:13:05,166

I saw something
that made me very happy

317

00:13:05,166 --> 00:13:07,000

and something
that made me very sad.

318

00:13:07,000 --> 00:13:09,100

The Hab was intact.
Yay!

319

00:13:09,100 --> 00:13:12,533

And the MAV was gone.
Boo!

320

00:13:12,533 --> 00:13:14,800

Right at that moment,
I knew I was screwed,

321

00:13:14,800 --> 00:13:17,233

but I didn't want to just die

out on the surface.

322

00:13:17,233 --> 00:13:20,300

I limped back to the Hab and
fumbled my way into an airlock.

323

00:13:20,300 --> 00:13:23,033

As soon as it equalized,
I threw off my helmet.

324

00:13:23,033 --> 00:13:24,500

Once inside the Hab,

325

00:13:24,500 --> 00:13:27,333

I doffed the suit and got my
first good look at the injury.

326

00:13:27,333 --> 00:13:28,933

It would need stitches.

327

00:13:28,933 --> 00:13:30,500

Fortunately, all of us
had been trained

328

00:13:30,500 --> 00:13:32,166

in basic medical procedures,

329

00:13:32,166 --> 00:13:34,400

and the Hab had excellent
medical supplies.

330

00:13:34,400 --> 00:13:36,233

A quick shot
of local anesthetic,

331

00:13:36,233 --> 00:13:39,266

irrigate the wound,
nine stitches, and I was done.

332

00:13:39,266 --> 00:13:41,333

I'd be taking antibiotics
for a couple of weeks,

333

00:13:41,333 --> 00:13:43,866

but other than that,
I'd be fine.

334

00:13:43,866 --> 00:13:45,166

I knew it was hopeless,

335

00:13:45,166 --> 00:13:47,433

but I tried firing up
the communications array.

336

00:13:47,433 --> 00:13:48,933

No signal, of course.

337

00:13:48,933 --> 00:13:51,400

The primary satellite dish
had broken off, remember?

338

00:13:51,400 --> 00:13:54,500

And it took
the reception array with it.

339

00:13:54,500 --> 00:13:57,533

The Hab had secondary and
tertiary communication systems,

340

00:13:57,533 --> 00:13:59,800

but they were both
just for talking to the MAV,

341

00:13:59,800 --> 00:14:01,700

which would use its
much more powerful systems

342

00:14:01,700 --> 00:14:03,066

to relay to Hermes.

343

00:14:03,066 --> 00:14:06,866

Thing is, that only works
if the MAV is still around.

344

00:14:06,866 --> 00:14:08,900

I had no way
to talk to Hermes.

345

00:14:08,900 --> 00:14:11,400

In time, I could locate the dish
out on the surface,

346

00:14:11,400 --> 00:14:13,933

but it would take weeks
for me to rig up any repairs,

347

00:14:13,933 --> 00:14:15,833

and by then,
it would be too late.

348

00:14:15,833 --> 00:14:17,566

In an abort,
Hermes would leave orbit

349

00:14:17,566 --> 00:14:18,900

within 24 hours.

350

00:14:18,900 --> 00:14:21,166

The orbital dynamics
made the trip safer and shorter

351

00:14:21,166 --> 00:14:23,900

the earlier you left,
so why wait?

352

00:14:23,900 --> 00:14:25,400

Checking out my suit,

353

00:14:25,400 --> 00:14:28,333
I saw the antenna had plowed
through my bio-monitor computer.

354
00:14:28,333 --> 00:14:31,133
When on an EVA, all the crew's
suits are networked

355
00:14:31,133 --> 00:14:33,066
so that we can see
each other's status.

356
00:14:33,066 --> 00:14:34,466
The rest of the crew

357
00:14:34,466 --> 00:14:36,900
would have seen the pressure
in my suit drop to nearly zero,

358
00:14:36,900 --> 00:14:40,200
followed immediately
by my bio-signs going flat.

359
00:14:40,200 --> 00:14:41,933
Add to that watching me
tumble down a hill

360
00:14:41,933 --> 00:14:44,466
with a spear through me
in the middle of a sandstorm,

361
00:14:44,466 --> 00:14:46,133
yeah, they thought I was dead.

362
00:14:46,133 --> 00:14:47,633
How could they not?

363
00:14:47,633 --> 00:14:49,233
They may have even
had a brief discussion

364

00:14:49,233 --> 00:14:50,800
about recovering my body.

365

00:14:50,800 --> 00:14:52,333
But regulations are clear.

366

00:14:52,333 --> 00:14:55,333
In the event a crewman dies
on Mars, he stays on Mars.

367

00:14:55,333 --> 00:14:57,733
Leaving his body behind
reduces weight for the MAV

368

00:14:57,733 --> 00:14:59,133
on the trip back.

369

00:14:59,133 --> 00:15:01,633
That means more disposable fuel
and a larger margin of error

370

00:15:01,633 --> 00:15:03,233
for the return thrust.

371

00:15:03,233 --> 00:15:05,866
No point in giving that up
for sentimentality.

372

00:15:05,866 --> 00:15:07,333
So that's the situation.

373

00:15:07,333 --> 00:15:08,800
I'm stranded on Mars.

374

00:15:08,800 --> 00:15:11,266
I have no way to communicate
with Hermes or Earth.

375

00:15:11,266 --> 00:15:12,866

Everyone thinks I'm dead.

376

00:15:12,866 --> 00:15:15,500

I'm in a Hab

designed to last 31 days.

377

00:15:15,500 --> 00:15:18,366

If the oxygenator breaks down,
I'll suffocate.

378

00:15:18,366 --> 00:15:21,166

If the water reclaimer
breaks down, I'll die of thirst.

379

00:15:21,166 --> 00:15:24,033

If the Hab breaches,
I'll just kind of explode.

380

00:15:24,033 --> 00:15:25,533

If none of those things happen,

381

00:15:25,533 --> 00:15:27,600

I'll eventually run out of food
and starve to death.

382

00:15:27,600 --> 00:15:29,133

So, yeah, I'm screwed."

383

00:15:29,133 --> 00:15:31,233

[laughter]

384

00:15:31,233 --> 00:15:32,433

Thank you.

385

00:15:32,433 --> 00:15:35,433

[applause]

386

00:15:40,166 --> 00:15:43,000

So I put a lot of work
into trying to make

387

00:15:43,000 --> 00:15:45,400

the science as accurate
as possible in this book,

388

00:15:45,400 --> 00:15:47,133

because at the time
that I wrote it,

389

00:15:47,133 --> 00:15:49,666

I was writing it for a small
core group of nerdy readers

390

00:15:49,666 --> 00:15:51,833

who were on my mailing list,

391

00:15:51,833 --> 00:15:54,233

'cause, initially,
I wrote it just--

392

00:15:54,233 --> 00:15:57,500

I published it a chapter
at a time to my website.

393

00:15:57,500 --> 00:16:00,900

And I had
about 3,000 regular readers,

394

00:16:00,900 --> 00:16:03,733

and that was it.

395

00:16:03,733 --> 00:16:06,933

But they were all, like,
hard-core science-y people,

396

00:16:06,933 --> 00:16:09,633

because that's the sort of stuff

that I wrote.

397

00:16:09,633 --> 00:16:12,733

So, I realized that I had to be accurate on the science,

398

00:16:12,733 --> 00:16:14,466

or as accurate as I could be.

399

00:16:14,466 --> 00:16:18,366

And, so that's why I put so much effort into scientific accuracy.

400

00:16:18,366 --> 00:16:20,233

I had no notion or concept

401

00:16:20,233 --> 00:16:22,133

that the book would have any mainstream appeal.

402

00:16:22,133 --> 00:16:24,433

I thought it would just be for dorks and geeks and dweebs

403

00:16:24,433 --> 00:16:26,000

and, you know, you.

404

00:16:26,000 --> 00:16:27,400

[laughter]

405

00:16:27,400 --> 00:16:28,566

So, um--

406

00:16:28,566 --> 00:16:31,466

And me, you know.

407

00:16:31,466 --> 00:16:34,500

So I was really surprised to see that it took off so well.

408

00:16:34,500 --> 00:16:36,633

And what I'm going to talk
to you about today

409

00:16:36,633 --> 00:16:38,566

is how science drove the plot.

410

00:16:38,566 --> 00:16:39,900

A lot of people ask me--

411

00:16:39,900 --> 00:16:42,133

So the book
has very simple formula--

412

00:16:42,133 --> 00:16:44,900

problem, solution, problem,
solution, problem, solution.

413

00:16:44,900 --> 00:16:46,900

And a question I get
asked a lot is,

414

00:16:46,900 --> 00:16:48,400

"Did you come up
with the problems first,

415

00:16:48,400 --> 00:16:50,166

or did you come up
with the solutions first

416

00:16:50,166 --> 00:16:52,100

and then work out a problem?"

417

00:16:52,100 --> 00:16:54,400

And the answer is, I came up
with the problems first.

418

00:16:54,400 --> 00:16:57,100

I tried to have
each problem be caused

419
00:16:57,100 --> 00:16:59,400
by the solution
to the previous problem.

420
00:16:59,400 --> 00:17:00,666
Like, "Oh, this broke,

421
00:17:00,666 --> 00:17:02,500
so I took apart
this other thing to fix that.

422
00:17:02,500 --> 00:17:04,233
Oh, well, now
the other thing doesn't work,"

423
00:17:04,233 --> 00:17:05,533
and so on.

424
00:17:05,533 --> 00:17:09,266
And so the whole plot
is driven by the realities

425
00:17:09,266 --> 00:17:12,166
of the physical world
that we live in

426
00:17:12,166 --> 00:17:14,733
or the one he lives on, anyway.

427
00:17:17,066 --> 00:17:19,700
It was interesting,
because just by sitting down

428
00:17:19,700 --> 00:17:21,800
and doing the math
on these things,

429

00:17:21,800 --> 00:17:24,600

just making

no pleasant assumptions

430

00:17:24,600 --> 00:17:26,666

and just doing

the math on everything,

431

00:17:26,666 --> 00:17:29,733

I kept finding

more and more problems.

432

00:17:29,733 --> 00:17:31,933

And that's good

because that's what I wanted.

433

00:17:31,933 --> 00:17:34,566

So one example is early on.

434

00:17:34,566 --> 00:17:37,733

Very early in the book,

he realizes--

435

00:17:37,733 --> 00:17:39,400

Like, in fact,

in the part I read,

436

00:17:39,400 --> 00:17:41,466

he realizes

he doesn't have enough food,

437

00:17:41,466 --> 00:17:44,600

and he goes about trying

to grow his own crops.

438

00:17:44,600 --> 00:17:46,033

He grows potatoes in the Hab

439

00:17:46,033 --> 00:17:48,600

to try to generate
enough calories to survive.

440

00:17:48,600 --> 00:17:50,900

And I was like, "Okay, well,
he's a botanist,

441

00:17:50,900 --> 00:17:52,733

so let's assume
he knows anything

442

00:17:52,733 --> 00:17:54,500

that I can look up," right?

443

00:17:54,500 --> 00:17:55,966

And so I said,

444

00:17:55,966 --> 00:17:58,133

"Okay, well how would
you grow potatoes on Mars?"

445

00:17:58,133 --> 00:18:00,466

Well, here's how you grow
potatoes, in general,

446

00:18:00,466 --> 00:18:03,933

and assume he's got adequate
lighting from internal lights

447

00:18:03,933 --> 00:18:05,300

and stuff like that.

448

00:18:05,300 --> 00:18:06,600

And one thing
I found out as well,

449

00:18:06,600 --> 00:18:08,333

it needs a medium to grow in.

450

00:18:08,333 --> 00:18:11,166

So he used just Martian soil
that he brought in,

451

00:18:11,166 --> 00:18:13,000

and then I'm like,
"Well, wait a minute.

452

00:18:13,000 --> 00:18:14,933

How much water
does that soil need?"

453

00:18:14,933 --> 00:18:16,900

'Cause Martian soil's
pretty dry.

454

00:18:16,900 --> 00:18:18,066

[laughs]

455

00:18:18,066 --> 00:18:20,066

And it turns out
he'd need something

456

00:18:20,066 --> 00:18:23,366

like 600 liters of water
to cover the soil

457

00:18:23,366 --> 00:18:26,566

to moisten the soil sufficiently
for potatoes to grow.

458

00:18:26,566 --> 00:18:30,466

And I was like, "There is no way
they'd bring 600 liters of water

459

00:18:30,466 --> 00:18:33,200

on a manned Mars mission when
they have a water reclaimer."

460

00:18:33,200 --> 00:18:34,333

All they need is, like,

461

00:18:34,333 --> 00:18:37,433

you know, some amount of water
in reserve

462

00:18:37,433 --> 00:18:39,466

to last them long enough
to evacuate

463

00:18:39,466 --> 00:18:40,933

if they lose their water system.

464

00:18:40,933 --> 00:18:44,000

They really don't need
to bring 600 liters of water.

465

00:18:44,000 --> 00:18:45,533

That's 600 kilograms.

466

00:18:45,533 --> 00:18:48,066

See, I did the math
there in my head.

467

00:18:48,066 --> 00:18:49,766

That's a lot of mass, right?

468

00:18:49,766 --> 00:18:51,133

And so I'm like,

469

00:18:51,133 --> 00:18:54,066

"How the hell is he going
to get 600 liters of water?"

470

00:18:54,066 --> 00:18:55,533

And then so I said, like,

471

00:18:55,533 --> 00:18:58,133

"All right, well, that's

a problem he's got to solve."

472

00:18:58,133 --> 00:18:59,566

And so it was really cool,
because--

473

00:18:59,566 --> 00:19:01,966

And then there's
this whole plotline in the book

474

00:19:01,966 --> 00:19:03,866

where he's manufacturing water.

475

00:19:03,866 --> 00:19:08,000

He's reducing leftover
hydrazine from the MDV

476

00:19:08,000 --> 00:19:09,466

to liberate the hydrogen.

477

00:19:09,466 --> 00:19:13,800

He can get oxygen by collecting
CO₂ from the Martian atmosphere

478

00:19:13,800 --> 00:19:15,566

and then running it
through the oxygenator

479

00:19:15,566 --> 00:19:16,833

to liberate the oxygen.

480

00:19:16,833 --> 00:19:18,166

Now he has hydrogen and oxygen,

481

00:19:18,166 --> 00:19:20,166

and he can put them together
to make water.

482

00:19:20,166 --> 00:19:22,666

Things don't go as smoothly
as he'd like on that process,

483

00:19:22,666 --> 00:19:26,133
especially the "mixing
the hydrogen and oxygen" part...

484

00:19:27,766 --> 00:19:29,800
But it's just
one of those examples

485

00:19:29,800 --> 00:19:32,266
of where just doing the math
and checking the science

486

00:19:32,266 --> 00:19:34,300
had huge effects on the plot.

487

00:19:34,300 --> 00:19:36,400
And that happened
over and over again.

488

00:19:36,400 --> 00:19:38,233
What I'm going
to show you now is--

489

00:19:38,233 --> 00:19:39,966
So I'm a software engineer,

490

00:19:39,966 --> 00:19:43,300
and I spent 25 years
writing software

491

00:19:43,300 --> 00:19:45,900
before I wrote "The Martian."

492

00:19:45,900 --> 00:19:48,833
When the only tool
you have is a hammer,

493

00:19:48,833 --> 00:19:52,166

every problem

starts to look like a nail.

494

00:19:52,166 --> 00:19:55,366

And so, when I was trying to

figure out the orbital dynamics

495

00:19:55,366 --> 00:19:59,100

of how Hermes got

between Earth and Mars,

496

00:19:59,100 --> 00:20:00,400

I was like,

497

00:20:00,400 --> 00:20:03,300

"Well, how do you do this?

How do you do this?"

498

00:20:03,300 --> 00:20:05,900

'Cause it's relatively easy

in orbital dynamics

499

00:20:05,900 --> 00:20:10,166

to figure out how to get a ship

from one point to another--

500

00:20:10,166 --> 00:20:13,266

an intercept orbit

or just a transfer orbit

501

00:20:13,266 --> 00:20:16,100

and then another thrust to match

the orbit of your target.

502

00:20:16,100 --> 00:20:18,400

It seems complicated,

503

00:20:18,400 --> 00:20:20,066

but in the grand scheme
of things,

504

00:20:20,066 --> 00:20:21,733
it's not that complicated,

505

00:20:21,733 --> 00:20:23,433
at least not
for a fiction writer

506

00:20:23,433 --> 00:20:25,900
where I don't need to have
the huge levels of accuracy

507

00:20:25,900 --> 00:20:28,500
that a real mission
would have, right?

508

00:20:28,500 --> 00:20:30,233
But I had no idea how to deal

509

00:20:30,233 --> 00:20:33,066
with a constantly
accelerating craft.

510

00:20:33,066 --> 00:20:35,233
Hermes is powered
by ion engines,

511

00:20:35,233 --> 00:20:38,333
which use, basically,
a nuclear reactor for power

512

00:20:38,333 --> 00:20:42,200
to rapidly accelerate,
in this case, argon atoms,

513

00:20:42,200 --> 00:20:45,800
such that they go so fast,
they pick up relativistic mass,

514

00:20:45,800 --> 00:20:49,500
which is why you don't need
nearly as much reactant mass.

515

00:20:49,500 --> 00:20:52,000
It has a much better
specific impulse

516

00:20:52,000 --> 00:20:55,100
than traditional
chemical rocket propellant.

517

00:20:55,100 --> 00:20:57,066
And it's a good way--
Hey, screen saver.

518

00:20:57,066 --> 00:21:01,900
It's a good way
to do interplanetary travel.

519

00:21:01,900 --> 00:21:03,400
And I'm like, "How the hell

520

00:21:03,400 --> 00:21:05,233
do I calculate
an orbital trajectory

521

00:21:05,233 --> 00:21:07,200
with a constantly
accelerating craft?"

522

00:21:07,200 --> 00:21:09,166
And I started trying
to do the math on this,

523

00:21:09,166 --> 00:21:11,066
and once I was, like,
ten integrals deep,

524

00:21:11,066 --> 00:21:13,633

I realized I was in
way over my head.

525

00:21:13,633 --> 00:21:16,433

And I went--I emailed around
to mathematicians and stuff,

526

00:21:16,433 --> 00:21:18,366

and they're like,
"I don't know. God be with you."

527

00:21:18,366 --> 00:21:20,533

[laughter]

528

00:21:20,533 --> 00:21:23,566

And so I said, like,
"Well, what does NASA do?"

529

00:21:23,566 --> 00:21:25,233

I mean, NASA,
they worked with--

530

00:21:25,233 --> 00:21:27,233

By the way, ion engines--
I didn't make this up.

531

00:21:27,233 --> 00:21:28,633

This is a real technology.

532

00:21:28,633 --> 00:21:31,533

Probably most of you know that,
but it's a real thing

533

00:21:31,533 --> 00:21:34,066

that has genuinely been used
in missions.

534

00:21:34,066 --> 00:21:38,733

Most recently the GRAIL mission
used ion propulsion.

535

00:21:38,733 --> 00:21:39,866

[light laughter]

536

00:21:39,866 --> 00:21:41,533

No?

They're laughing.

537

00:21:41,533 --> 00:21:43,900

Dawn.

Well, Dawn also. Yeah.

538

00:21:43,900 --> 00:21:46,566

[laughs]

539

00:21:46,566 --> 00:21:50,233

The moon--

The ones that mapped the moon.

540

00:21:50,233 --> 00:21:51,400

They didn't?

- No.

541

00:21:51,400 --> 00:21:52,733

- Oh, oh, I'm wrong.

- Dawn did.