
WHAT'S
ON BOARD
SPACEX'S CRS-21 MISSION TO THE
INTERNATIONAL SPACE STATION

1
00:00:16,590 --> 00:00:19,460
BIOASTEROID IS AN EXPERIMENT
TO STUDY WHETHER WE CAN USE

2
00:00:19,460 --> 00:00:24,110
MICROORGANISMS, BACTERIA, OR
FUNGI TO EXTRACT ECONOMICALLY

3
00:00:24,110 --> 00:00:26,870
INTERESTING ELEMENTS
FROM ASTEROID MATERIAL.

4
00:00:26,900 --> 00:00:30,350
IT'S ESSENTIALLY WHAT WE WOULD
CALL A BIOMINING EXPERIMENT.

5
00:00:30,530 --> 00:00:33,290
AND WE HOPE TO LEARN WHETHER
WE CAN USE MICROBES TO

6
00:00:33,290 --> 00:00:36,560
EXTRACT THINGS LIKE RARE-EARTH
ELEMENTS AND OTHER ELEMENTS

7
00:00:36,860 --> 00:00:40,670
THAT CAN BE USED TO SUSTAIN A
SELF-SUSTAINING HUMAN PRESENCE

8
00:00:40,760 --> 00:00:41,990
THROUGHOUT THE SOLAR SYSTEM.

9
00:00:41,990 --> 00:00:44,960
IN OTHER WORDS MINING IS
SUPPORT OF THE LONG-TERM

10
00:00:44,960 --> 00:00:47,410
HUMAN EXPLORATION AND
SETTLEMENT OF SPACE.

11

00:00:47,599 --> 00:00:51,570
BIOASTEROID IS
BASICALLY THE NATURAL

12
00:00:51,960 --> 00:00:54,970
FOLLOWING UP OF BIOROCK.

13
00:00:55,185 --> 00:00:59,475
SO WHILE WITH BIOROCK WE FIRST
INVESTIGATED TERRESTRIAL ROCKS

14
00:00:59,655 --> 00:01:02,065
WITH THREE DIFFERENT TYPES
OF BACTERIA WITH BIOASTEROID

15
00:01:02,085 --> 00:01:05,235
WE ARE GOING TO USE REAL
EXTRATERRESTRIAL ROCKS THAT

16
00:01:05,235 --> 00:01:08,655
IS GOING TO BE ASTEROID, OF
COURSE, AND THE TWO DIFFERENT

17
00:01:08,655 --> 00:01:10,005
TYPES OF MICROORGANISMS.

18
00:01:10,025 --> 00:01:13,565
ONE IS A BACTERIUM AGAIN
THAT WAS USED ALREADY WITH

19
00:01:13,565 --> 00:01:16,335
BIOROCK AND THE SECOND ONE
IS GOING TO BE A FUNGUS,

20
00:01:16,425 --> 00:01:17,895
A PENICILLIUM FUNGUS.

21
00:01:18,345 --> 00:01:20,555
THE BIOROCK EXPERIMENT
DEMONSTRATED THAT WE WERE

22
00:01:20,555 --> 00:01:24,105
ABLE TO USE BACTERIA TO
EXTRACT RARE-EARTH ELEMENTS

23
00:01:24,105 --> 00:01:27,705
WHICH ARE USED IN YOUR MOBILE
PHONES AND ELECTRONICS FROM

24
00:01:27,705 --> 00:01:30,725
BASALT, WHICH IS AN ANALOG
MATERIAL FOR WHAT MUCH OF

25
00:01:30,725 --> 00:01:32,520
THE MOON AND MARS IS MADE UP.

26
00:01:32,610 --> 00:01:34,890
AND BIOASTEROID IS GOING TO
FOLLOW THAT UP BY SAYING,

27
00:01:34,890 --> 00:01:37,540
WELL, OKAY, NOW WE CAN SHOW
THAT WE CAN GET RARE-EARTH

28
00:01:37,560 --> 00:01:41,160
ELEMENTS OUT OF BASALT ON THE
MOON AND MARS, CAN WE DO

29
00:01:41,160 --> 00:01:42,900
BIOMINING ON ASTEROIDS
AS WELL?

30
00:01:42,900 --> 00:01:44,640
SO WE'RE GOING TO BE
LOOKING AT WHETHER THOSE

31
00:01:44,640 --> 00:01:47,860
MICROBES CAN GET ELEMENTS
WE'D REALLY LIKE TO USE IN

32
00:01:47,880 --> 00:01:50,850
INDUSTRY FROM THE SURFACE
AND INTERIOR OF ASTEROIDS.

33
00:01:51,230 --> 00:01:53,340
EXPERIMENTS SUCH AS
BIOROCK AND BIOASTEROID

34
00:01:53,340 --> 00:01:57,690
CAN REALLY HELP DEVELOPING
SUSTAINABLE, A SUSTAINABLE

35
00:01:57,690 --> 00:01:59,090
FUTURE OF HUMANS IN SPACE.

36
00:02:04,070 --> 00:02:05,119
HERE ON THE GROUND.

37
00:02:05,179 --> 00:02:08,090
IF YOU GO TO A HOSPITAL OR A
CLINIC AND YOU HAVE A MEDICAL

38
00:02:08,090 --> 00:02:12,109
PROBLEM, LIKE AN INFECTION,
YOU OFTEN GET A BLOOD TEST

39
00:02:12,109 --> 00:02:14,840
CALLED A WHITE BLOOD CELL
COUNT AND DIFFERENTIAL.

40
00:02:15,410 --> 00:02:18,749
THAT'S A CAPABILITY WE DON'T
HAVE RIGHT NOW IN SPACEFLIGHT.

41
00:02:18,800 --> 00:02:21,680
SO FOR EXPLORATION MISSIONS,
WHEN WE WANT TO GO TO THE MOON

42
00:02:21,680 --> 00:02:24,650

AND MARS, WE ARE GOING TO HAVE
TO TAKE OUR ASTRONAUTS AND

43
00:02:24,650 --> 00:02:28,640
MAKE THEM MORE SELF-SUFFICIENT
AND MORE CAPABLE ON THEIR OWN.

44
00:02:28,935 --> 00:02:33,584
SO OUR OBJECTIVE IS TO TEST
OUT THIS DEVICE THAT CAN BE

45
00:02:33,584 --> 00:02:37,035
USED FOR CLINICAL MEDICINE
IN SPACE SO THE ASTRONAUTS

46
00:02:37,065 --> 00:02:39,945
CAN DIAGNOSE AND TREAT
THEIR OWN MEDICAL PROBLEMS.

47
00:02:40,575 --> 00:02:43,095
THE DEVICE THAT WE'RE
USING WAS DEVELOPED ON THE

48
00:02:43,095 --> 00:02:46,274
GROUND UNDER THE GRAVITY
CONDITIONS OF EARTH.

49
00:02:46,695 --> 00:02:49,245
AND WHAT WE ARE TRYING TO
DO ON THE SPACE STATION

50
00:02:49,484 --> 00:02:52,125
IS DEMONSTRATE THAT IT
CAN STILL WORK IN THE

51
00:02:52,155 --> 00:02:53,325
ABSENCE OF GRAVITY.

52
00:02:53,685 --> 00:02:56,804
SO AS FLUIDS MOVE AROUND

WITHIN THE MACHINE AND IT

53
00:02:56,804 --> 00:02:59,864
DOES ITS BLOOD ANALYZING
WORK, WE WANT TO MAKE SURE

54
00:02:59,864 --> 00:03:03,165
THOSE FLUIDS MOVE PROPERLY
IN THE SPACE ENVIRONMENT.

55
00:03:03,465 --> 00:03:07,875
OUR GOAL IN THIS WORK IS
REALLY TO TRY AND EXPAND WHAT

56
00:03:07,875 --> 00:03:10,605
WE CAN DO IN SPACE FLIGHT
FROM A MEDICAL PERSPECTIVE,

57
00:03:10,935 --> 00:03:14,295
BECAUSE WHEN WE SEND PEOPLE
TO MARS AND SOMEONE GETS SICK

58
00:03:14,295 --> 00:03:16,905
ON THE WAY TO MARS, WE HAVE TO
BE ABLE TO TAKE CARE OF THEM,

59
00:03:16,935 --> 00:03:21,734
WHERE THEY ARE INSTEAD OF
FOCUSING ON BEING ABLE TO GET

60
00:03:21,734 --> 00:03:22,785
THEM BACK TO EARTH QUICKLY.

61
00:03:25,080 --> 00:03:28,530
WE ARE SENDING BRAIN ORGANOIDS
TO THE SPACE STATION.

62
00:03:28,760 --> 00:03:31,850
A BRAIN ORGANOID IS A
MINIATURIZED VERSION OF

63
00:03:32,830 --> 00:03:34,360
DEVELOPING HUMAN BRAINS.

64
00:03:34,360 --> 00:03:37,070
SO THIS REALLY MIMICS
THE EARLY STAGES OF A

65
00:03:37,070 --> 00:03:38,390
HUMAN BRAIN DEVELOPMENT.

66
00:03:38,990 --> 00:03:42,950
OUR FIRST MISSION WAS TO TEST
IF THE BRAIN ORGANOIDS COULD

67
00:03:42,950 --> 00:03:46,280
ACTUALLY SURVIVE INTO THIS
MICROGRAVITY ENVIRONMENT.

68
00:03:46,580 --> 00:03:49,330
THE SECOND MISSION
HAS TWO MAIN GOALS.

69
00:03:49,440 --> 00:03:53,114
THE FIRST ONE IS A VALIDATION
OF THE FIRST MISSIONS, BUT

70
00:03:53,114 --> 00:03:56,695
WE ARE ALSO ADDING A MORE
MECHANISTIC EXTRAPOLATION

71
00:03:56,715 --> 00:03:59,760
OR INSIGHTS WHERE WE ARE
GOING TO BE MANIPULATING THE

72
00:03:59,760 --> 00:04:02,940
TELOMERES ACTIVITY INSIDE
THESE BRAIN ORGANOIDS.

73

00:04:02,959 --> 00:04:06,140
THESE BRAIN ORGANOIDS ALTHOUGH
THEY ARE HUMAN MODELS.

74
00:04:06,140 --> 00:04:09,950
SO THEY HAVE A GREAT POTENTIAL
TO STUDY HUMAN DISORDERS

75
00:04:09,980 --> 00:04:13,220
THEY ARE ACTUALLY MIMICKING
THE VERY EARLY STAGES OF

76
00:04:13,220 --> 00:04:14,630
THE HUMAN BRAIN DEVELOPMENT.

77
00:04:14,729 --> 00:04:16,890
THERE IS FOR US NO
WAY TO DO THIS TYPE

78
00:04:16,890 --> 00:04:18,079
OF RESEARCH ON EARTH.

79
00:04:18,320 --> 00:04:20,240
SO WE WILL REALLY NEED
TO GO OUT THERE IN

80
00:04:20,240 --> 00:04:22,840
SPACE TO SEE WHAT'S THE
IMPACT OF MICROGRAVITY.

81
00:04:22,840 --> 00:04:25,480
BEING ABLE TO PERHAPS
ACCELERATE THESE BRAIN

82
00:04:25,480 --> 00:04:29,920
ORGANOID MATURATION COULD
HELP US MAKE BETTER HUMAN

83
00:04:29,920 --> 00:04:33,160
MODELS FOR NEURODEGENERATIVE

DISORDERS, FOR WHICH FOR

84
00:04:33,160 --> 00:04:35,830
MOST OF THEM, WE DON'T HAVE
ANY TREATMENTS OR CURES.

85
00:04:36,120 --> 00:04:41,310
WHAT MAKES ME REALLY EXCITED
ABOUT SPACE IS THE POSSIBILITY

86
00:04:41,310 --> 00:04:46,094
TO IMPROVE DISEASE MODELS
AND THEIR CONTRIBUTION TO

87
00:04:46,094 --> 00:04:51,145
FUTURE HUMAN SPACE TRAVEL
MISSIONS OR COLONIZATION

88
00:04:51,164 --> 00:04:52,065
AND OTHER PLANETS.

89
00:04:52,305 --> 00:04:55,395
THIS MIGHT SEEM LIKE SCIENCE
FICTION, BUT I FEEL THAT

90
00:04:55,395 --> 00:04:58,215
THAT THE MOMENT IS REALLY
POSITIVE RIGHT NOW FOR

91
00:04:58,215 --> 00:04:59,295
THIS KIND OF RESEARCH.

92
00:05:03,045 --> 00:05:05,115
THE STUDY THAT WE DID
ABOUT FIVE, SIX YEARS

93
00:05:05,115 --> 00:05:09,284
AGO, WE SENT UP IPS
CELL-DERIVED CARDIOMYOCYTES.

94
00:05:09,545 --> 00:05:11,974
THERE'S A FEW THINGS THAT MAY
HAVE MADE ME GASP OUT LOUD

95
00:05:11,974 --> 00:05:13,115
UP ON BOARD SPACE STATION.

96
00:05:13,115 --> 00:05:15,395
SEEING THE PLANET WAS ONE
OF THEM, BUT I GOT TO SAY

97
00:05:15,695 --> 00:05:17,974
GETTING THE CELLS IN FOCUS
AND WATCHING HEART CELLS

98
00:05:17,974 --> 00:05:20,495
ACTUALLY BEAT HAS BEEN
ANOTHER PRETTY BIG ONE.

99
00:05:20,855 --> 00:05:24,425
FOR THIS PARTICULAR STUDY,
WE'RE GOING TO GO ONE STEP

100
00:05:24,425 --> 00:05:28,505
FURTHER TO MAKE IT RESEMBLE
MORE OF A HUMAN HEART,

101
00:05:28,815 --> 00:05:31,724
MEANING THAT NOT JUST THE
CARDIOMYOCYTES, BUT WE'RE

102
00:05:31,745 --> 00:05:34,724
SENDING IT IN A CHUNK OF
THE HUMAN HEART TISSUE

103
00:05:34,724 --> 00:05:37,905
THAT HAS CARDIOMYOCYTES,
THE FIBROBLASTS AND

104

00:05:37,905 --> 00:05:39,164
THE ENDOTHELIAL CELLS.

105
00:05:39,455 --> 00:05:43,148
WE PUT THE THREE CELLS
TOGETHER TO FORM WHAT WE CALL

106
00:05:43,148 --> 00:05:47,388
3D ENGINEERED HEART TISSUES
AND OUR PLAN IS TO SEND THESE

107
00:05:47,388 --> 00:05:51,588
CONTRACTING 3D ENGINEERED
HEART TISSUESS UP TO SPACE

108
00:05:51,678 --> 00:05:54,718
SO THAT WE CAN UNDERSTAND
THE EFFECT OF MICROGRAVITY

109
00:05:55,138 --> 00:05:58,783
ON CARDIAC FUNCTION
IN HUMAN HEART TISSUE.

110
00:05:59,013 --> 00:06:01,393
THIS IS THE SCAFFOLD
THAT HOLDS THE

111
00:06:01,393 --> 00:06:02,463
ENGINEERED HEART TISSUES.

112
00:06:02,463 --> 00:06:07,353
SO ONE SCAFFOLD CONTAINS
FOUR OF THESE TISSUES

113
00:06:07,653 --> 00:06:08,433
WHEN THEY ARE BEATING.

114
00:06:08,553 --> 00:06:12,993
IF YOU THINK ABOUT IT THE
HUMAN EVOLUTION TOOK PLACE

115
00:06:13,023 --> 00:06:16,983
UNDER THE INFLUENCE OF THIS
UNSEEN FORCE THAT IS GRAVITY.

116
00:06:17,338 --> 00:06:20,018
AND IF YOU TAKE THAT
FUNDAMENTAL FORCE OUT, IT

117
00:06:20,018 --> 00:06:23,638
IS SOMETHING THAT THE CELLS
HAVE NOT EXPERIENCED BEFORE.

118
00:06:23,698 --> 00:06:27,628
SO THERE'S A LOT OF
CHALLENGES, AND WE ARE GLAD

119
00:06:27,628 --> 00:06:31,528
TO BE A PART OF A TEAM THAT
OFFERS SOLUTIONS AT EVERY STEP

120
00:06:31,528 --> 00:06:36,148
OF THE WAY, THAT HAS MADE US
TO GET TO THIS POINT WHERE

121
00:06:36,148 --> 00:06:38,758
WE ARE CONFIDENT THAT OUR
SCIENCE IS GOING TO PUSH THE

122
00:06:38,758 --> 00:06:41,728
FRONTIERS OF CARDIOVASCULAR
RESEARCH TO THE NEXT LEVEL.

123
00:06:46,628 --> 00:06:51,693
OUR RESEARCH IS DEVOTED TO
THE PROBLEM OF RESOLVING

124
00:06:51,693 --> 00:06:56,003
THE DAMAGE THAT MAY BE
CAUSED BY MICROMETEORITES

125
00:06:56,173 --> 00:07:01,383
AND SPACE DEBRIS ON
MANMADE OBJECTS IN SPACE.

126
00:07:01,743 --> 00:07:06,453
WE ARE TRYING TO UNDERSTAND
WHETHER WE CAN USE THE OLD

127
00:07:06,483 --> 00:07:11,323
TECHNOLOGY CALLED BRAZING
TO EXECUTE THE PROCESS IN

128
00:07:11,323 --> 00:07:16,573
REAL TIME AND IN SITU, BUT
BEFORE WE GO INTO DEVELOPMENT

129
00:07:16,573 --> 00:07:19,753
OF THE TECHNOLOGY, WE HAVE
TO UNDERSTAND THE PHYSICS

130
00:07:19,753 --> 00:07:23,173
OF THE PROBLEM AND THAT
UNDERSTANDING OF THE PHYSICS

131
00:07:23,173 --> 00:07:28,193
REQUIRES EXPERIMENTATION
UNDER BOTH TERRESTRIAL AND

132
00:07:28,193 --> 00:07:30,913
SPACE MICROGRAVITY CONDITIONS.

133
00:07:31,693 --> 00:07:35,923
WE ARE BUILDING THE
EXPERIMENTAL SAMPLES, WHICH

134
00:07:35,953 --> 00:07:40,378
ARE GOING TO BE DELIVERED TO
THE SPACE STATION AND THEN

135
00:07:40,378 --> 00:07:44,158
USED IN THE EQUIPMENT THAT IS
ALREADY IN THE SPACE STATION.

136
00:07:44,458 --> 00:07:47,278
IN PARALLEL, WE ARE
REPEATING EXACTLY THE SAME

137
00:07:47,278 --> 00:07:50,518
SET OF EXPERIMENTS UNDER
TERRESTRIAL CONDITIONS,

138
00:07:51,178 --> 00:07:54,688
PERFORMING THE SAME SET
OF ANALYSIS, COMPARING THE

139
00:07:54,688 --> 00:07:59,008
TWO AND CONCLUDING WHETHER
OR NOT THERE ARE IMPORTANT

140
00:07:59,008 --> 00:08:03,028
DIFFERENCES RELATED TO THE
IMPACT OF GRAVITY OR NOT.

141
00:08:03,448 --> 00:08:06,088
WE ARE TRYING TO
UNDERSTAND WHETHER THE

142
00:08:06,088 --> 00:08:10,388
SAME PHENOMENON THAT WE
OBSERVED UNDER TERRESTRIAL

143
00:08:10,408 --> 00:08:14,218
CONDITIONS CAN TAKE PLACE
UNDER SPACE CONDITIONS.

144
00:08:18,498 --> 00:08:19,468
MY NAME IS BROCK HOWE.

145

00:08:19,518 --> 00:08:22,038
I'M PROJECT MANAGER FOR
THE NANORACKS AIRLOCK

146
00:08:22,038 --> 00:08:23,118
THAT YOU SEE BEFORE US.

147
00:08:23,268 --> 00:08:25,818
THIS IS THE, GOING TO BE
THE FIRST COMMERCIAL MODULE

148
00:08:25,818 --> 00:08:29,258
FOR THE INTERNATIONAL
SPACE STATION, DESIGNED AND

149
00:08:29,278 --> 00:08:30,988
BUILT HERE AT NANORACKS.

150
00:08:31,338 --> 00:08:33,648
WE'VE BEEN WORKING ON THE
AIRLOCK FOR ABOUT FIVE YEARS.

151
00:08:33,648 --> 00:08:35,538
IT'S GOING TO BE A NEW
AIRLOCK TO THE SPACE

152
00:08:35,538 --> 00:08:40,128
STATION, SIMILAR IN USE
AS THE JAPANESE AIRLOCK.

153
00:08:40,188 --> 00:08:42,318
BUT THIS ONE'S ABOUT
FIVE TIMES THE SIZE OF

154
00:08:42,318 --> 00:08:43,268
THE JAPANESE AIRLOCK.

155
00:08:43,818 --> 00:08:46,578
OPPORTUNITIES FOR SCIENTISTS
TO DO WORK AND BE CREATIVE

156
00:08:46,578 --> 00:08:49,358
WITH THE AIRLOCK ARE A
MYRIAD OF DIFFERENT WAYS.

157
00:08:49,358 --> 00:08:52,188
ONE OF THE PRIMARY THINGS
IS DEPLOYING OBJECTS OFF

158
00:08:52,188 --> 00:08:52,948
OF THE SPACE STATION.

159
00:08:52,948 --> 00:08:55,188
NANORACKS DOES THAT
ON THESE SMALL CUBESAT

160
00:08:55,903 --> 00:08:57,253
TYPE FORMAT RIGHT NOW.

161
00:08:57,343 --> 00:08:59,983
THE AIRLOCK WILL PROVIDE A
CAPABILITY OF MUCH LARGER,

162
00:09:00,223 --> 00:09:02,473
LARGER VOLUMES OF THOSE
TYPES OF PAYLOADS TO BE

163
00:09:02,473 --> 00:09:03,653
DEPLOYED OUT INTO SPACE.

164
00:09:03,963 --> 00:09:06,663
WE ALSO HAVE EXTERNAL PAYLOAD
MOUNTS WHERE WE CAN HOST

165
00:09:06,663 --> 00:09:07,943
PAYLOADS ON THE AIRLOCK.

166
00:09:08,313 --> 00:09:10,833
WE CAN ALSO HOST PAYLOADS

INSIDE THE AIR LOCK WHILE IT'S

167
00:09:10,853 --> 00:09:12,303
STILL BIRTHED TO NODE THREE.

168
00:09:12,693 --> 00:09:14,493
SO THERE'S A LOT OF
DIFFERENT ENVIRONMENTS THAT

169
00:09:14,493 --> 00:09:15,483
THE SCIENTISTS CAN USE.

170
00:09:15,813 --> 00:09:18,033
A LOT OF DIFFERENT VOLUMES
THAT SCIENTISTS CAN USE,

171
00:09:18,303 --> 00:09:21,063
A LOT OF DIFFERENT PAYLOAD
POWER AND DATA CAPABILITIES

172
00:09:21,063 --> 00:09:23,923
ONBOARD THE AIRLOCK THAT
REALLY WILL ENHANCE THEIR

173
00:09:23,923 --> 00:09:26,923
ABILITY TO DO SOME REALLY
COOL SCIENCE ON BOARD ISS.

174
00:09:27,213 --> 00:09:30,003
THE AIRLOCK ALSO REPRESENTS
FOR NANORACKS THE NEXT STEP

175
00:09:30,003 --> 00:09:32,993
TOWARDS OUR GOALS, WHICH ARE
COMMERCIAL SPACE STATIONS.

176
00:09:32,993 --> 00:09:36,663
SO THIS PROVIDES A LOT OF
CAPABILITIES TO ENHANCE OUR

177
00:09:36,663 --> 00:09:39,363
ENGINEERING CAPABILITIES AND
OUR FABRICATION CAPABILITIES