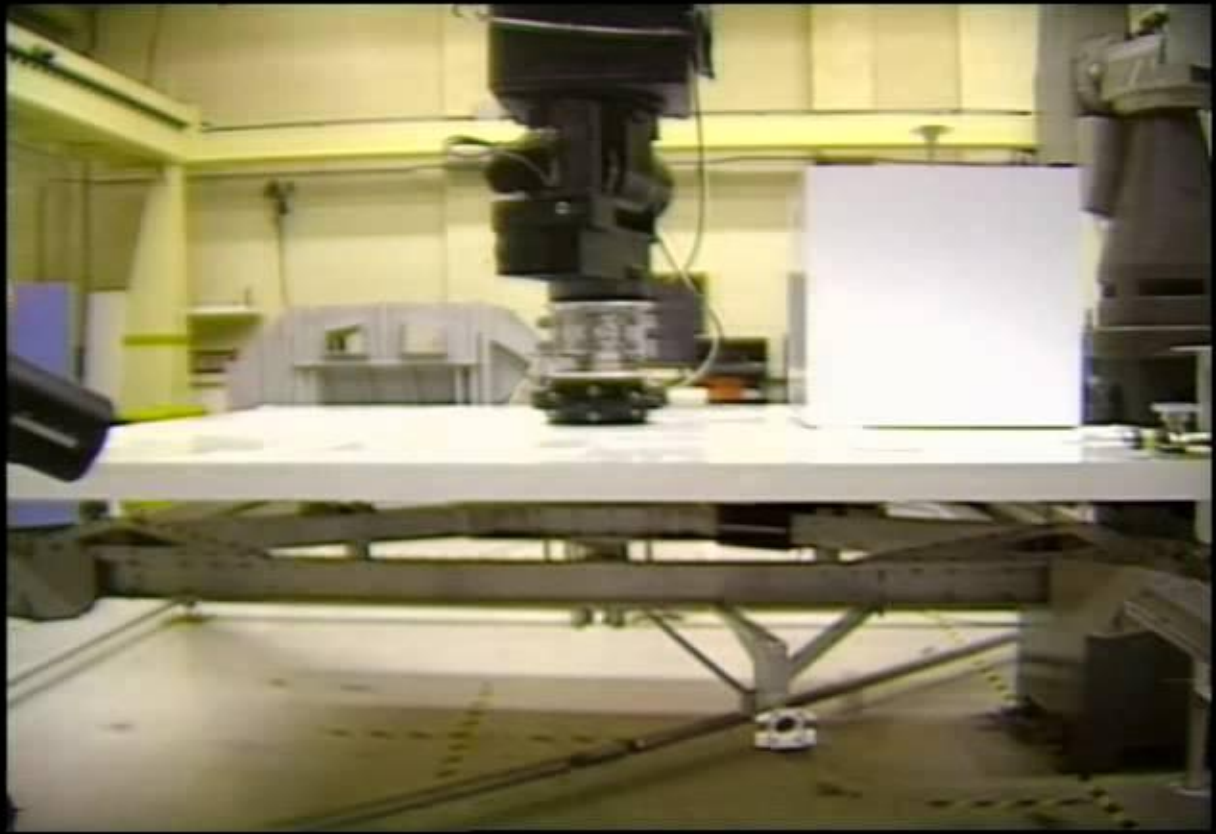

1
00:00:07,829 --> 00:00:06,070
the robot laboratory was established at

2
00:00:10,549 --> 00:00:07,839
goddard to prepare for the flight tele

3
00:00:11,990 --> 00:00:10,559
robotics servicer fts operations on the

4
00:00:14,310 --> 00:00:12,000
space station

5
00:00:16,150 --> 00:00:14,320
it contained several elements graphic

6
00:00:18,630 --> 00:00:16,160
simulations for defining engineering

7
00:00:21,109 --> 00:00:18,640
criteria definition of operational

8
00:00:23,269 --> 00:00:21,119
scenarios which show how the fts will

9
00:00:25,589 --> 00:00:23,279
operate on space station task

10
00:00:28,070 --> 00:00:25,599
decomposition which breaks the robot

11
00:00:30,390 --> 00:00:28,080
operations down to primitive tasks to

12
00:00:32,470 --> 00:00:30,400
see how they perform on space station

13
00:00:35,270 --> 00:00:32,480

operator interfaces and workstation

14
00:00:44,950 --> 00:00:35,280
designs software development and

15
00:00:49,350 --> 00:00:47,110
here you see a picture of the fts in the

16
00:00:51,110 --> 00:00:49,360
shuttle bay preparing to assemble an

17
00:00:52,229 --> 00:00:51,120
attached payload station interface

18
00:00:54,549 --> 00:00:52,239
adapter

19
00:00:56,709 --> 00:00:54,559
this equipment will interface attached

20
00:00:59,270 --> 00:00:56,719
payloads to the space station

21
00:01:01,349 --> 00:00:59,280
the remote manipulator system or rms in

22
00:01:04,149 --> 00:01:01,359
the space shuttle bay is preparing to

23
00:01:06,390 --> 00:01:04,159
lift the station interface adapter sia

24
00:01:13,990 --> 00:01:06,400
out of the cargo bay in close proximity

25
00:01:19,030 --> 00:01:16,870
the fts is erected next to the sia and

26
00:01:32,469 --> 00:01:19,040
deploys one of the legs from its stowed

27
00:01:36,710 --> 00:01:34,630
after the leg is deployed the others are

28
00:01:39,190 --> 00:01:36,720
subsequently deployed and the sia is

29
00:01:40,870 --> 00:01:39,200
brought up to the structural trust nodes

30
00:01:42,789 --> 00:01:40,880
by the fts

31
00:01:45,670 --> 00:01:42,799
this allows the interface adapter to be

32
00:01:48,310 --> 00:01:45,680
secured in a soft dock position

33
00:01:50,710 --> 00:01:48,320
following this the fts through a tool

34
00:01:52,870 --> 00:01:50,720
attached to its end defector brings the

35
00:02:06,709 --> 00:01:52,880
joint in close proximity and fastens it

36
00:02:11,990 --> 00:02:09,190
the rms now goes back to the cargo bay

37
00:02:14,869 --> 00:02:12,000
and lifts a deck carrier with an oru or

38
00:02:17,350 --> 00:02:14,879

orbital replacement unit out of the bay

39
00:02:19,030 --> 00:02:17,360
bringing it in close proximity to the

40
00:02:23,830 --> 00:02:19,040
sie

41
00:02:26,869 --> 00:02:23,840
the deck carrier and brings the two

42
00:02:28,630 --> 00:02:26,879
together to hard dock or secure the two

43
00:02:31,110 --> 00:02:28,640
elements a crank is turned which

44
00:02:37,509 --> 00:02:31,120
actuates the lead screw mechanism

45
00:02:42,710 --> 00:02:40,390
this is a description of a hierarchical

46
00:02:43,509 --> 00:02:42,720
ada language robot programming system

47
00:02:44,550 --> 00:02:43,519
are

48
00:02:48,949 --> 00:02:44,560
harps

49
00:02:52,390 --> 00:02:48,959
using the nazrim architecture which

50
00:02:54,390 --> 00:02:52,400
stands for nasa reference model

51
00:02:55,990 --> 00:02:54,400
this is the architecture established by

52
00:02:58,550 --> 00:02:56,000
the national institute of science and

53
00:03:00,229 --> 00:02:58,560
technology and it is hierarchical in its

54
00:03:02,869 --> 00:03:00,239
form

55
00:03:05,110 --> 00:03:02,879
on the left is sensor processing

56
00:03:06,710 --> 00:03:05,120
in the middle world models of the fts

57
00:03:07,990 --> 00:03:06,720
and its environment

58
00:03:10,630 --> 00:03:08,000
and on the right

59
00:03:12,550 --> 00:03:10,640
task decomposition

60
00:03:14,630 --> 00:03:12,560
at the very lowest levels it has been

61
00:03:17,350 --> 00:03:14,640
implemented to operate with joysticks on

62
00:03:22,470 --> 00:03:17,360
a simulated robot to show how the robot

63
00:03:26,309 --> 00:03:24,149

here's a picture of the operator working

64
00:03:28,470 --> 00:03:26,319
with joysticks to bring the simulated

65
00:03:30,869 --> 00:03:28,480
end effector of the robot in proximity

66
00:03:40,390 --> 00:03:30,879
to a handle on the orbital replacement

67
00:03:44,710 --> 00:03:42,149
you'll notice it turns yellow when

68
00:03:46,949 --> 00:03:44,720
approaching the handle and red when it

69
00:03:48,789 --> 00:03:46,959
actually contacts it

70
00:03:57,350 --> 00:03:48,799
this permits the operator to learn the

71
00:04:01,750 --> 00:03:59,429
the fts operational simulator has

72
00:04:03,990 --> 00:04:01,760
performed various tasks as you have seen

73
00:04:05,350 --> 00:04:04,000
in the software simulation the leg

74
00:04:07,509 --> 00:04:05,360
deployment

75
00:04:09,990 --> 00:04:07,519
the docking to the truss the duct

76
00:04:11,589 --> 00:04:10,000
carrier movement to the sie the hard

77
00:04:15,110 --> 00:04:11,599
docking and in addition the thermal

78
00:04:17,189 --> 00:04:15,120
coupler and enter oru exchange

79
00:04:19,110 --> 00:04:17,199
these tasks were built with full-scale

80
00:04:21,830 --> 00:04:19,120
models of space station hardware and

81
00:04:32,150 --> 00:04:21,840
utilized floor-mounted puma or research

82
00:04:36,790 --> 00:04:34,390
here's the operator workstation with the

83
00:04:38,230 --> 00:04:36,800
operator using joysticks to control the

84
00:04:40,870 --> 00:04:38,240
robot arms

85
00:04:43,270 --> 00:04:40,880
here the gantry robot which emulates the

86
00:04:45,749 --> 00:04:43,280
rms brings the station interface adapter

87
00:04:48,230 --> 00:04:45,759
sia to the side of the truss

88
00:04:50,150 --> 00:04:48,240

the puma robot is positioning itself to

89
00:04:51,670 --> 00:04:50,160
the handle on the leg through a machine

90
00:04:56,230 --> 00:04:51,680
vision system

91
00:04:58,469 --> 00:04:56,240
through a camera and computer will

92
00:05:07,670 --> 00:04:58,479
recognize four dots on the white

93
00:05:12,790 --> 00:05:10,070
aligning the tool and end effector to

94
00:05:14,950 --> 00:05:12,800
the target the end effector is inserted

95
00:05:16,870 --> 00:05:14,960
into the hole or in the end effector

96
00:05:28,230 --> 00:05:16,880
jaws are closed to fasten it to the

97
00:05:32,150 --> 00:05:30,469
once engaged the robots through the

98
00:05:34,469 --> 00:05:32,160
operator in the computer will bring the

99
00:05:37,029 --> 00:05:34,479
leg to the deployed position

100
00:06:05,189 --> 00:05:37,039
once deployed a latching system keeps

101
00:06:09,670 --> 00:06:07,830
at this point the robot disengages from

102
00:06:10,870 --> 00:06:09,680
the leg and is placed in a stowed

103
00:06:13,029 --> 00:06:10,880
condition

104
00:06:15,670 --> 00:06:13,039
the gantry now lowers the station

105
00:06:18,550 --> 00:06:15,680
interface adapter onto the truss face

106
00:06:20,390 --> 00:06:18,560
where it is soft docked which means that

107
00:06:22,230 --> 00:06:20,400
a latching system will keep it in

108
00:06:24,870 --> 00:06:22,240
position so that when the gantry is

109
00:06:27,189 --> 00:06:24,880
removed there will be no motion of the

110
00:06:29,749 --> 00:06:27,199
station interface adapter

111
00:06:33,189 --> 00:06:29,759
in the space world when the rms leaves

112
00:06:35,590 --> 00:06:33,199
the sia doesn't disengage from the truss

113
00:06:38,390 --> 00:06:35,600

and now the robot comes down

114
00:06:41,189 --> 00:06:38,400
and fastens a nut connecting a screw

115
00:06:41,990 --> 00:06:41,199
into the node of the space station truss

116
00:06:51,270 --> 00:06:42,000
by

117
00:06:55,749 --> 00:06:53,670
now the gantry picks up the deck carrier

118
00:06:58,309 --> 00:06:55,759
and the attached payload and moves it to

119
00:07:00,309 --> 00:06:58,319
the truss sia interface

120
00:07:03,749 --> 00:07:00,319
this is all pre-programmed into the

121
00:07:05,510 --> 00:07:03,759
gantry controller in real life the rms

122
00:07:06,950 --> 00:07:05,520
will be operated from the aft flight

123
00:07:08,870 --> 00:07:06,960
deck of the shuttle

124
00:07:11,510 --> 00:07:08,880
in future months in the laboratory a

125
00:07:13,430 --> 00:07:11,520
mock-up of the aft flight deck will

126
00:07:33,830 --> 00:07:13,440
permit a crewman to operate the gantry

127
00:07:38,309 --> 00:07:35,830
now the deck carrier is brought down

128
00:07:39,990 --> 00:07:38,319
onto the sia through a series of pins

129
00:07:42,390 --> 00:07:40,000
and cones underneath

130
00:07:43,189 --> 00:07:42,400
it aligns itself and drops on the soft

131
00:07:45,510 --> 00:07:43,199
dock

132
00:07:47,909 --> 00:07:45,520
lead screw held in the center

133
00:07:50,070 --> 00:07:47,919
this has a motorized nut which if the

134
00:07:52,469 --> 00:07:50,080
proper power were available would draw

135
00:07:54,629 --> 00:07:52,479
the deck carrier to the sia

136
00:07:57,110 --> 00:07:54,639
the robot in the event of power outage

137
00:07:58,550 --> 00:07:57,120
or no power availability can manually

138
00:08:00,710 --> 00:07:58,560

crank the screw

139
00:08:02,629 --> 00:08:00,720
as shown here to bring the deck carrier

140
00:08:16,309 --> 00:08:02,639
and the sie in the assembled

141
00:08:20,950 --> 00:08:18,469
the robot now moves over to a thermal

142
00:08:22,950 --> 00:08:20,960
coupler this is an extension device

143
00:08:24,710 --> 00:08:22,960
which would permit fluids which are

144
00:08:27,110 --> 00:08:24,720
needed by the attached payload to be

145
00:08:28,390 --> 00:08:27,120
joined to the main utility lines on the

146
00:08:30,390 --> 00:08:28,400
space station

147
00:08:32,149 --> 00:08:30,400
the handle which you will notice is a

148
00:08:34,310 --> 00:08:32,159
common handle we use to interface the

149
00:08:35,589 --> 00:08:34,320
robotic end effector to the task it will

150
00:08:37,670 --> 00:08:35,599
be doing

151
00:08:39,110 --> 00:08:37,680
it lifts one half of the coupler which

152
00:08:41,990 --> 00:08:39,120
would have a hose connection to the

153
00:08:44,149 --> 00:08:42,000
payload down to the leg of the sia which

154
00:08:58,870 --> 00:08:44,159
simulates the position of the thermal

155
00:09:02,630 --> 00:09:01,110
a soft dock connection is then made

156
00:09:05,110 --> 00:09:02,640
which would permit the coupler to be

157
00:09:06,829 --> 00:09:05,120
held together while the end effector is

158
00:09:09,269 --> 00:09:06,839
released to do other

159
00:09:11,750 --> 00:09:09,279
operations this is the first step

160
00:09:13,990 --> 00:09:11,760
required to make the connection you'll

161
00:09:24,310 --> 00:09:14,000
see that the robot arm is twisting the

162
00:09:28,310 --> 00:09:25,910
indications on the screen for the

163
00:09:30,550 --> 00:09:28,320

operator on his left shown as yellow

164
00:09:32,230 --> 00:09:30,560
bars indicate the positions of the

165
00:09:33,829 --> 00:09:32,240
joints of the robot

166
00:09:36,070 --> 00:09:33,839
in the center of the bar shot the

167
00:09:38,870 --> 00:09:36,080
vertical bars indicate the forces on the

168
00:09:40,550 --> 00:09:38,880
coupler when they are reduced to zero it

169
00:09:42,470 --> 00:09:40,560
means that there is no stress on the

170
00:09:44,630 --> 00:09:42,480
coupler and it will stay in position

171
00:09:53,750 --> 00:09:44,640
when released you'll notice the same

172
00:09:59,190 --> 00:09:56,310
the jaws close in the reset position and

173
00:10:01,829 --> 00:09:59,200
now the robot moves over to a collar

174
00:10:03,829 --> 00:10:01,839
containing a screw which when actuated

175
00:10:06,150 --> 00:10:03,839
as shown brings the two couplers

176
00:10:16,389 --> 00:10:06,160
together to finally fasten the two

177
00:10:21,670 --> 00:10:19,190
in this configuration shown the robot is

178
00:10:25,190 --> 00:10:21,680
opening a door to a simulated attached

179
00:10:27,190 --> 00:10:25,200
payload the door is opened by the robot

180
00:10:29,670 --> 00:10:27,200
this is to simulate the exchange of an

181
00:10:31,990 --> 00:10:29,680
inter-orbital replacement unit of a

182
00:10:34,949 --> 00:10:32,000
failed component or film package

183
00:10:37,030 --> 00:10:34,959
exchange for an instrument for instance

184
00:10:39,910 --> 00:10:37,040
the robot goes through its motions

185
00:10:50,550 --> 00:10:39,920
autonomously that is the computer has

186
00:10:55,590 --> 00:10:53,110
now the robot reaches into the inner box

187
00:11:06,470 --> 00:10:55,600
attaches itself to the oru

188
00:11:12,230 --> 00:11:09,670

it then places the oru on a stand which

189
00:11:15,430 --> 00:11:12,240
has been designed to accept a receptacle

190
00:11:48,150 --> 00:11:15,440
on the bottom for power conditioning and

191
00:11:53,430 --> 00:11:50,389
the next series of tests were performed

192
00:11:55,590 --> 00:11:53,440
on the engineering test bed

193
00:11:58,629 --> 00:11:55,600
this test bed contains a pair of seven

194
00:11:59,910 --> 00:11:58,639
degree of freedom robot arms and hand

195
00:12:02,629 --> 00:11:59,920
controllers

196
00:12:04,710 --> 00:12:02,639
it is used to develop control algorithms

197
00:12:07,590 --> 00:12:04,720
or mathematical laws to determine the

198
00:12:09,990 --> 00:12:07,600
robot operation a safety system to

199
00:12:12,230 --> 00:12:10,000
protect the robot from collisions in

200
00:12:14,710 --> 00:12:12,240
defectors for gripping objects in the

201
00:12:17,110 --> 00:12:14,720
space environment and dynamic models in

202
00:12:20,069 --> 00:12:17,120
order to replicate zero gravity motions

203
00:12:21,110 --> 00:12:20,079
and determine instabilities

204
00:12:23,350 --> 00:12:21,120
here

205
00:12:25,509 --> 00:12:23,360
the operator is controlling the large

206
00:12:28,230 --> 00:12:25,519
seven degree of freedom robot

207
00:12:30,069 --> 00:12:28,240
by seven degrees of freedom it contains

208
00:12:33,030 --> 00:12:30,079
unlike the puma robots you've seen

209
00:12:35,269 --> 00:12:33,040
before an additional joint which permits

210
00:12:37,829 --> 00:12:35,279
it to reach around objects much as the

211
00:12:40,470 --> 00:12:37,839
elbow of a human arm

212
00:12:42,310 --> 00:12:40,480
it is shown in the upright position

213
00:12:44,870 --> 00:12:42,320

the operator has a mini master hand

214
00:12:45,910 --> 00:12:44,880
controller which is a replication of his

215
00:12:48,389 --> 00:12:45,920
arm

216
00:12:52,150 --> 00:12:48,399
every motion he makes is followed by the

217
00:12:54,389 --> 00:12:52,160
robot in a master slave operation

218
00:12:57,030 --> 00:12:54,399
now the operator is bringing the end

219
00:12:59,509 --> 00:12:57,040
effector which has roller grippers for

220
00:13:01,190 --> 00:12:59,519
secure mating to the side of a handle on

221
00:13:03,590 --> 00:13:01,200
the white column

222
00:13:05,990 --> 00:13:03,600
you will notice he uses his fingers to

223
00:13:08,470 --> 00:13:06,000
index the arm

224
00:13:11,190 --> 00:13:08,480
indexing means small motions in the arm

225
00:13:13,509 --> 00:13:11,200
left and right will permit large motions

226
00:13:15,990 --> 00:13:13,519
in the robot arm such that the operator

227
00:13:18,829 --> 00:13:16,000
does not have to make inordinate motions

228
00:13:20,550 --> 00:13:18,839
to move the slave robot through large

229
00:13:22,710 --> 00:13:20,560
trajectories

230
00:13:24,870 --> 00:13:22,720
now the operator is lining the end

231
00:13:26,870 --> 00:13:24,880
effector up to the handle

232
00:13:29,190 --> 00:13:26,880
in future days we will have what is

233
00:13:30,870 --> 00:13:29,200
called force reflection in the handle

234
00:13:32,949 --> 00:13:30,880
such that when the operator makes

235
00:13:34,389 --> 00:13:32,959
contact with the handle and closes the

236
00:13:36,470 --> 00:13:34,399
jaws of the gripper

237
00:13:39,189 --> 00:13:36,480
forces of connections will be felt by

238
00:13:41,829 --> 00:13:39,199

the operator so that he gets a feel for

239
00:14:00,310 --> 00:13:41,839
the operation and permits more dextrous

240
00:14:04,389 --> 00:14:02,230
the next sequence shows the dexterity of

241
00:14:06,389 --> 00:14:04,399
the robot with its large number of

242
00:14:09,509 --> 00:14:06,399
degrees of freedom it can move through a

243
00:14:11,509 --> 00:14:09,519
very wide sphere of motion here it is

244
00:14:13,269 --> 00:14:11,519
shown reaching up in back of a camera

245
00:14:16,069 --> 00:14:13,279
which is mounted on the top

246
00:14:18,389 --> 00:14:16,079
if indeed the camera were out of focus

247
00:14:19,670 --> 00:14:18,399
or needed repositioning the robot could

248
00:14:22,470 --> 00:14:19,680
essentially

249
00:14:24,949 --> 00:14:22,480
change the camera position if needed

250
00:14:26,150 --> 00:14:24,959
essentially it can do maintenance on

251
00:14:27,990 --> 00:14:26,160
itself

252
00:14:47,750 --> 00:14:28,000
you will notice the very dexterous

253
00:14:52,069 --> 00:14:49,829
the lab expansion program has been

254
00:14:54,150 --> 00:14:52,079
designed as a new construction of

255
00:14:56,790 --> 00:14:54,160
facilities initiative in order to

256
00:14:58,870 --> 00:14:56,800
provide more space for users research

257
00:15:00,150 --> 00:14:58,880
activities and flight hardware

258
00:15:03,030 --> 00:15:00,160
integration

259
00:15:05,189 --> 00:15:03,040
it contains fifteen thousand square feet

260
00:15:07,430 --> 00:15:05,199
and would cost approximately three and a

261
00:15:09,829 --> 00:15:07,440
half million dollars to build

262
00:15:11,910 --> 00:15:09,839
we're hoping to get it ready in mid 1990

263
00:15:13,829 --> 00:15:11,920

however the current plan is to have it

264
00:15:22,550 --> 00:15:13,839
in a state of readiness by the end of

265
00:15:27,590 --> 00:15:25,030
here is an artist concept of the lab on

266
00:15:30,470 --> 00:15:27,600
the right the laboratories that exist

267
00:15:32,710 --> 00:15:30,480
today with the gantry robot the control

268
00:15:35,350 --> 00:15:32,720
workstation and the mezzanine for

269
00:15:37,269 --> 00:15:35,360
software development on the left we have

270
00:15:39,509 --> 00:15:37,279
the expanded building which will house

271
00:15:41,910 --> 00:15:39,519
two laboratory modules

272
00:15:44,069 --> 00:15:41,920
the modules emulate the lab modules on

273
00:15:46,389 --> 00:15:44,079
the space station from which astronauts

274
00:15:48,150 --> 00:15:46,399
can operate in a simulated environment

275
00:15:50,150 --> 00:15:48,160
housed at the other end of the building

276
00:15:52,150 --> 00:15:50,160
the new extension will have many robots

277
00:15:54,790 --> 00:15:52,160
for doing research work advanced

278
00:15:56,710 --> 00:15:54,800
technology and clean room integration of

279
00:15:59,030 --> 00:15:56,720
flight articles before they migrate to

280
00:16:01,030 --> 00:15:59,040
the main laboratory for testing

281
00:16:04,150 --> 00:16:01,040
this facility will permit upgrading