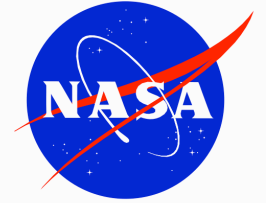


# Automating Stowage Operations for the International Space Station

Russell Knight, Gregg Rabideau,  
Andrew Mishkin, Young Lee

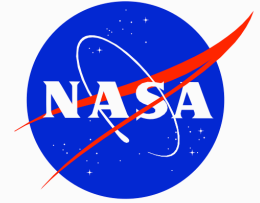


# Stowage



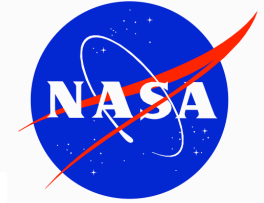
- Storing and retrieving items
- 25% of astronaut time is spent on stowage
  - Retrieving items for activities
  - Storing items after activities or when found
  - Prepacking items to be shipped out
  - Unpacking items that are being shipped in

# Scenario 1: found item



- Astronaut calls down for a location for a found item.
  - Identify the item
    - Part Number, Serial Number, Barcode, Description, Cage code, Location (both general and specific)
  - Find a place for it
    - Where it was, e.g., whatever is indicated in the IMS database
    - Where it “should” go
      - Size, like parts together

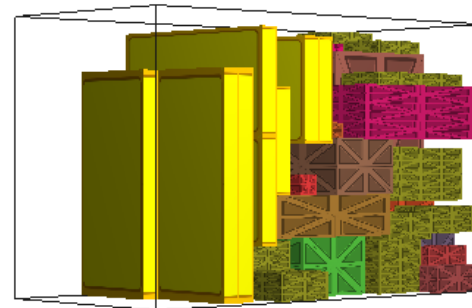
# Demo Location Suggestion



ASIMO: 3D Stowage Utility V1.0.6 (Console)

Update from DB Search seg 3311 div

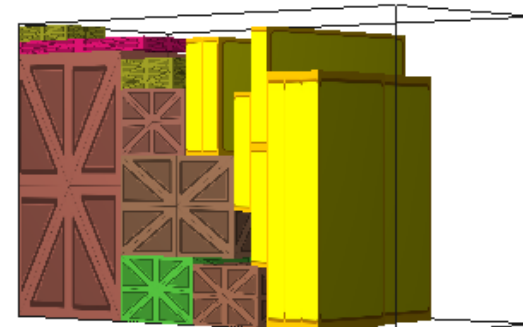
New Item	Part Number	Serial Number	Acronym
Select	SEG33111841-317	2750	CTB Half Divider
Select	SEG33111841-317	2778	CTB Half Divider
Select	SEG33111841-317	2781	CTB Half Divider
Select	SEG33111841-317	2518	CTB Half Divider
Select	SEG33111841-317	2589	CTB Half Divider
Select	SEG33111841-317	NA_FLT10A_00030	CTB Half Divider
Select	SEG33111841-317	2838	CTB Half Divider
Select	SEG33111841-317	NA_FLT31P_00086	CTB Half Divider



ASIMO: 3D Stowage Utility V1.0.6 (Console)

Update from DB Search seg 3311 div

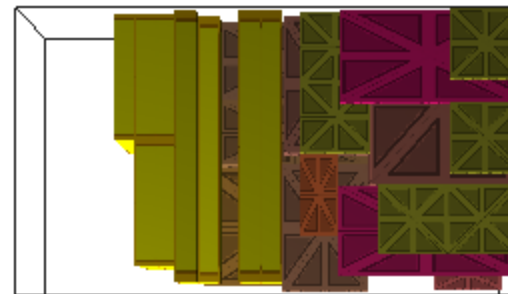
Quantity	Part Number	Serial Number	Acronym
10	SEG33111841-317	2750	CTB Half Divider
Clear	Get next locations	10	

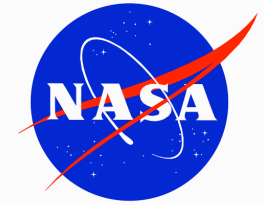


ASIMO: 3D Stowage Utility V1.0.6 (Console)

Update from DB Search seg 3311 div

Quantity	Part Number	Serial Number
10	SEG33111841-317	2750
Clear	Get next locations	10
COL ID3 (SEG33111840-303 1106) (10) 26.0		
NOD IP1 (SEG33111837-301 1015) (10) 16.833		
PMA1 (SEG33111836-303 1171) (1) 16.833		
NOD IO4_D1 (SEG33111838-307 1141) (1) 16.833		
COL ID2_A (SEG33111838-307 1466) (8) 13.229		
COL ID5 (SODI-01-1524-1000-000-VE NA_FLT17A_00901) (8) 11.979		
COL ID1 (SEG33111836-303 1410) (4) 11.979		
COL ID3_A (SEG33111840-303 1165) (10) 11.562		
COL ID4_rack front (SEG33111838-307 1472) (5) 11.562		
COL ID2_rack front (67215MEAB23200 2001) (10) 11.312		





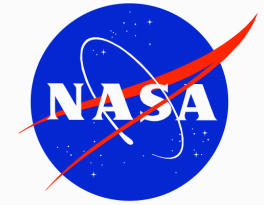
# Location Suggestion

For each **container**, in “matching” order

For each count  $n$  of items to place, in increasing order

Try to place  $n$  items, as well as the existing contents, in the container

If we succeed, then add it to the solution list



# Packing Algorithm

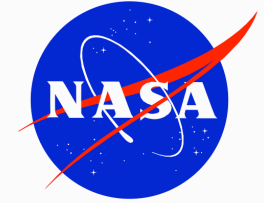
- Find the 5 largest items to be packed.
- For every possible orientation and packing of these items that fits, try to **pack the rest of the items**

- Why 5?
  - Mostly empirical
  - Branching factor



Items	Packings
1	6
2	72
3	864
4	10368
5	124416
6	1492992

# Pack the rest of the items



- **Squeaky Wheel Optimization**

Assign an initial priority based on the sum of the squares of the length, width, and height

Loop 100 times

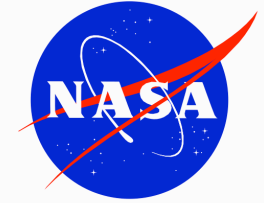
For each box, in descending priority order

**Attempt to place**

If we fail, increase the priority of the box

If all boxes are placed, return **success**

# Attempt to place



- Given a box, container, set of placed boxes, and a set of open positions

For each position, in order of proximity to the left lower far corner of the container

For each orientation, in decreasing order of the **orientation score**

If the box is contained and intersects no other box

Remove the position from the open positions

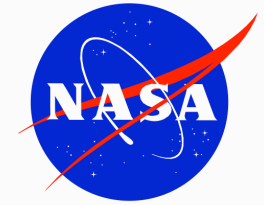
Add newly induced positions to the open positions

return **success**

Return **failure**



# Orientation score



- Assume we:
  - want to pack the container with only boxes of a single type
  - must use the same orientation for all
  - what orientation allows us to pack the most?

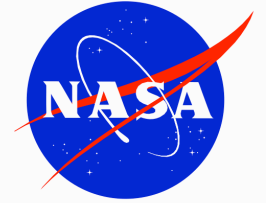
- Computable in constant time

For each orientation  $o$  (total of 6)

↑  
Orient the box according to  $o$  (adjust the width, height, and length)

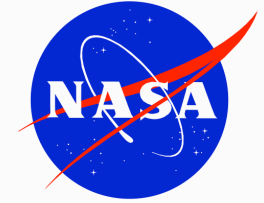
$o.score = \text{int}(\text{container.width}/\text{box.width}) * \text{int}(\text{container.height}/\text{box.height}) * \text{int}(\text{container.length}/\text{box.length})$

# What about bags?



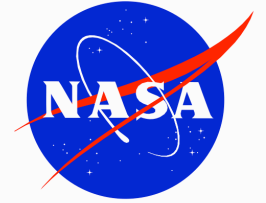
- Large bags, e.g. CTBs, become rectangular solids when packed tightly
  - Not amorphous
- Small bags, e.g., Ziplocs, can be ignored and their contents can be “emptied” into the containing container
  - Infinitely amorphous

# Beyond Location Suggestion



- Prepack List generation
  - ISS crew members pack containers of items to leave station
  - Use the packing technology to automatically pack the bags
- Unpack List generation
  - ISS crew members unpack containers and store the items
  - Use the packing technology to automatically stow all of the incoming items
    - Crew Preference – special items with special locations

# Acknowledgements



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  - Ursula Stockdale, Casey Johnson, Robert Adams
  - Kary “Scott” Smith
  - Larry “Joey” Crawford, Margaret Gibb, and Roger Galpin.