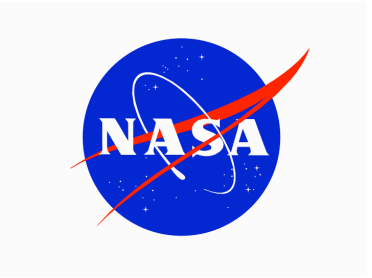
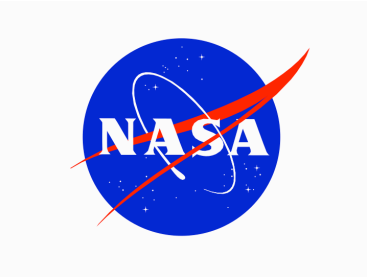
JPL Clearance CL 13-1386



Automating Stowage Operations for the International Space Station

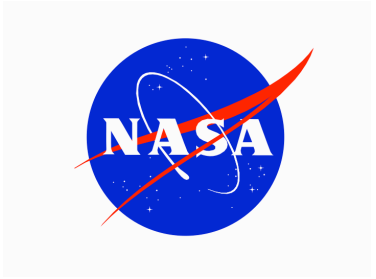
Russell Knight, Gregg Rabideau,
Andrew Mishkin, Young Lee

Stowage



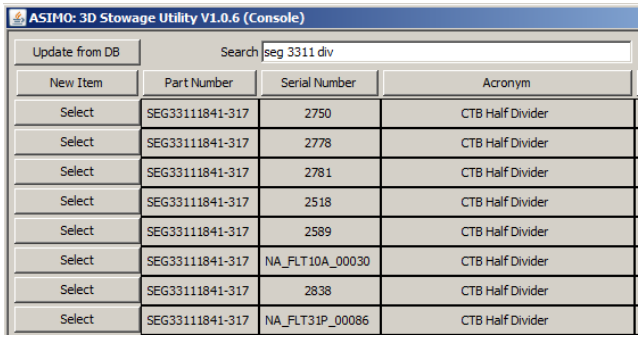
- Storing and retrieving items
- 25% of astronaut time is spent on stowage
  - Retrieving items for activities
  - Storing items after activities or when found
  - Prepacking items to be shipped out
  - Unpacking items that are being shipped in

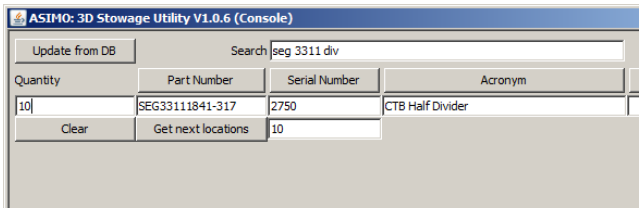
Scenario 1: found item

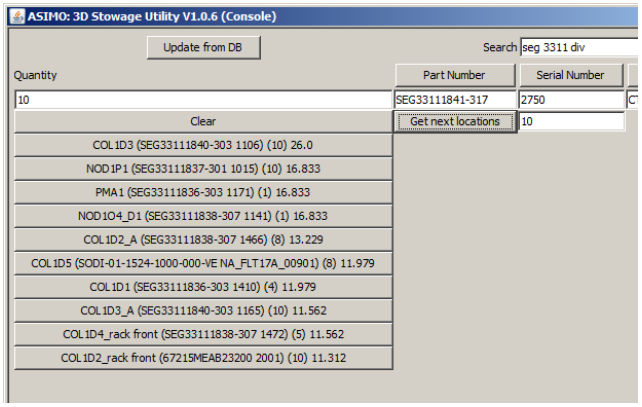


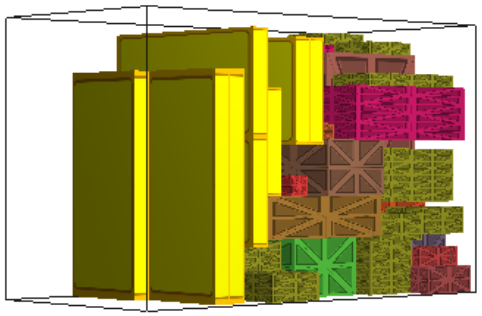
- Astronaut calls down for a location for a found item.
  - Identify the item
    - Part Number, Serial Number, Barcode, Description, Cage code, Location (both general and specific)
  - Find a place for it
    - Where it was, e.g., whatever is indicated in the IMS database
    - Where it "should" go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

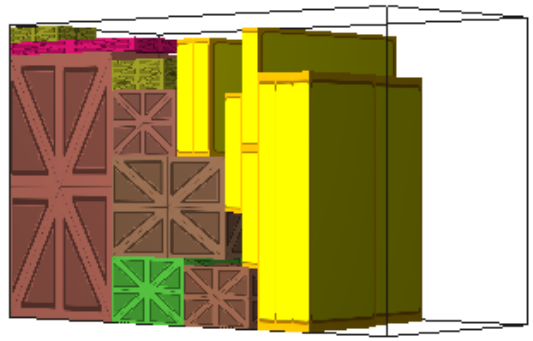
Demo Location Suggestion

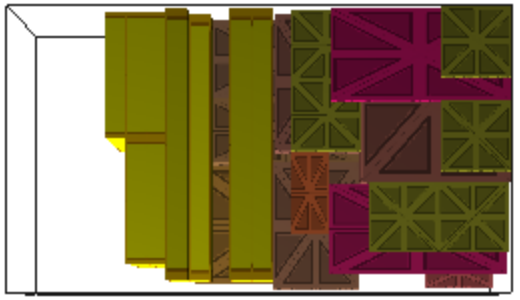




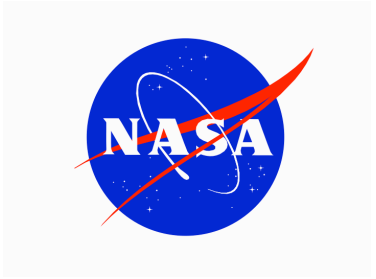








Location Suggestion



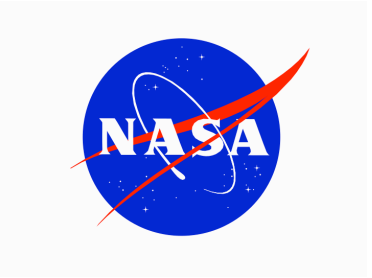
For each **container**, in "matching" order

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

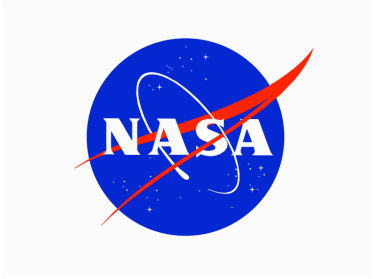
Packing Algorithm



- 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

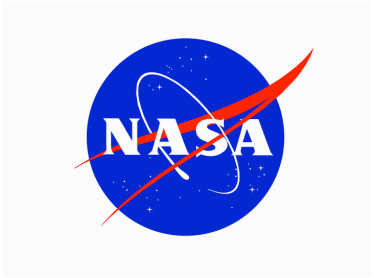
  For each box, in descending priority order

    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

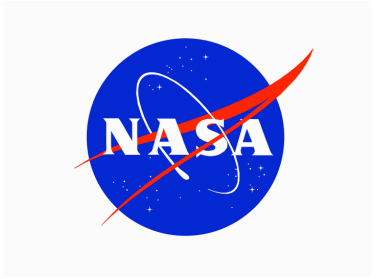
      Remove the position from the open positions

      Add newly induced positions to the open positions

      return **success**

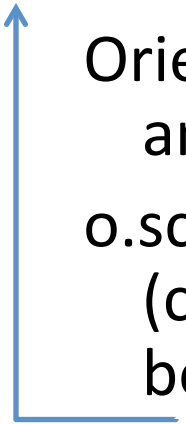
Return **failure**

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

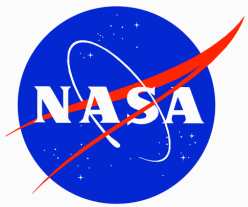
For each orientation o (total of 6)



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

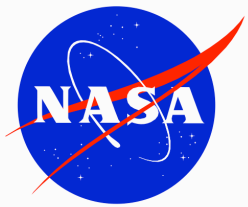
o.score = int(container.width/box.width) * int (container.height/box.height) * int(container.length/ box.length)

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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