UtiliStation: Increasing the Utilization of the International Space Station with Big Data Analytics for Stowage

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INTRODUCTION

The International Space Station, is one of the most complex & expensive structures built by mankind with worldwide investigations.

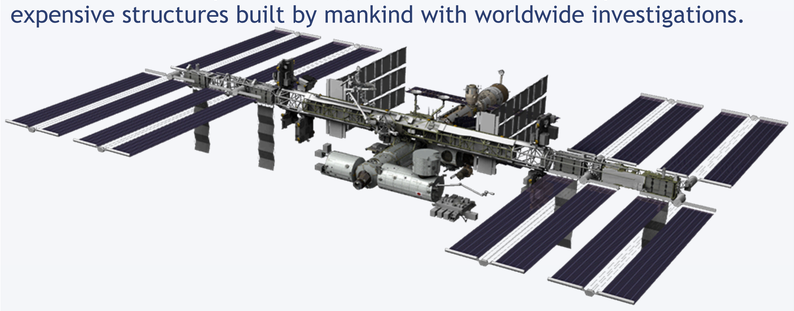
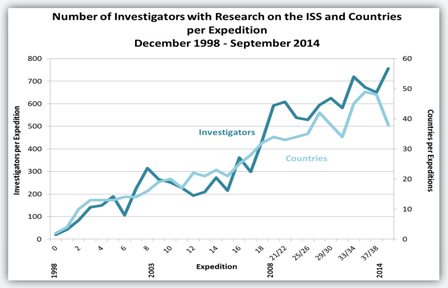


Image NASA.gov: The International Space Station US Segment is a National Lab



Credit: ISS Utilization Statics July, 2015 NASA.gov

ISS Investigations:

- Biology and Bio-Tech
- Earth & Space Science
- Educational Outreach
- Human Research
- Physical Science
- Technology

	ISS Expeditions 0-40
Number of Investigations	1765
Number of Investigators	2484
Countries with Investigations	83

ISS Utilization Statistics July, 2015

It is beneficial to mankind to have the ISS operating as efficiently as possible.

PROBLEM

Investigations onboard the ISS are expensive to conduct. More efficient use of resources like astronaut time could lead to more investigations.

Stowage bags in airlock on ISS. NASA.gov

ISS Expeditions	39/40	0-40
Upmass	2,141 kg	52,742 kg
Downmass	763 kg	12,743 kg
Crew time	1,898 kg	23,765 kg

Credit: ISS Utilization Statics July, 2015 NASA.gov

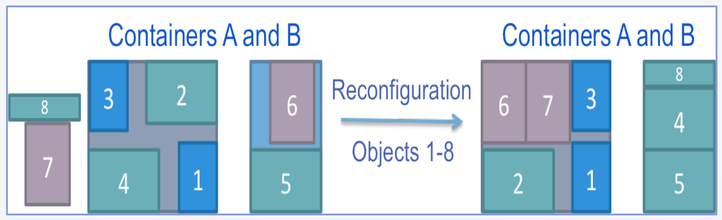
- Getting hardware to the ISS is costly and complicated, though the price has recently dropped from $10,000 per pound to $3,000 per pound with commercial spaceflight.
- There are tens of thousands of tracked items onboard the ISS.
- Accumulated cargo may lead to wasted search time.
- Astronaut time is limited and costly, making search time expensive.

Optimizations on placement and management of cargo may reduce human management costs and allow for more astronaut time and ultimately better utilization of the International Space Station.

STOWAGE AND SCHEDULE

Optimizations on stowage locations, placement, configuration and reconfiguration-in-time can lead to better time utilization.

- Different cargo configurations can allow for more or less capacity.
- Reconfiguration requires extra space, e.g. must temp move objects.
- Reconfiguration requires time to move objects between locations.
- Automated techniques can optimize initial and in-time placement.



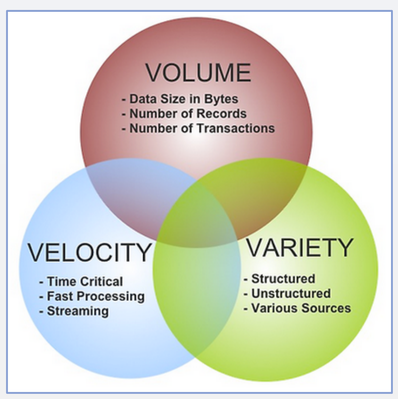
- Finding optimal configurations is known to be NP-hard.
- Similar techniques can be used for optimizing object access times.

Mock schedule times for Flight Engineers (FE) show that there is limited time for re-organizing stowage.

	5:30	6:00	6:30	7:00	7:30	8:00	8:30	9:00
FE1	Sleep	Wake			Procedure A1		Procedure A2	Procedure A3
FE2	Sleep	Sleep	Wake		Procedure B1			Procedure B2
FE3	Sleep	Wake		Procedure C1			Procedure C2	
FE4	Sleep	Wake	Procedure D1			Procedure D2	Procedure D3	
FE5	Wake			Procedure E1	Procedure E2	Procedure E3		Procedure E4

BACKGROUND

Emerging Big Data and Analytics methods allow for optimizations.
3 V's of Big Data:



VOLUME –
- Tens of thousands of objects
- Hundreds of events
- Placement options
- NP-complete configurations

VELOCITY –
- Time critical
- Changing configurations
- On-the-fly reconfigurations

VARIETY –
- Database data
- Procedure data

Data analytics is the process of collecting and analyzing data using qualitative and quantitative techniques to discover useful information or enhance productivity.

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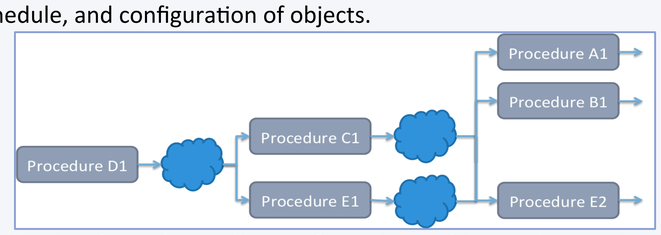
Optimizations on cargo placement as well as configurations can achieve better utilization of space and time. Complete optimizations can be shown to be NP-hard.

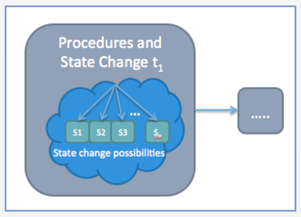
APPROACH

Reducing the complexity based on the time available for reconfiguration can simply the problem.

Goal: Minimize time required for procedures given a set of procedures, schedule, and configuration of objects.



- Allowing for only small reconfigurations of items due to time and space constrains can improve utilization.
- Collapsing procedures and reconfigurations into time steps creates a smaller search space.



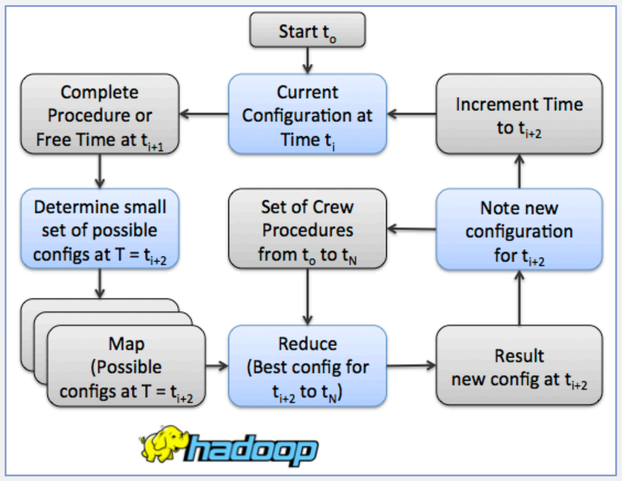
Example Procedure:

Gather Items
...
Perform Procedure
...
Return Items

DATA ANALYSIS

Optimized location placement of objects can be shown to be NP-hard, though Linear Programming, LP, solutions exist that achieve near optimum results.

- Small time between completion of event t_{i+1} and next time t_{i+2}, so only small configuration changes are possible.
- Another constraint is physical space required for reconfiguration which also reduces the search space.



Limited reconfiguration time and space reduces data for map and reduction phase to allow UtiliStation procedure to be realized.

CONCLUSIONS AND CONTINUED RESEARCH

- Forward work includes collaborating with NASA and integrating and executing with example data and performing additional analysis.
- Increased productivity and utilization of the ISS may be possible.
- Reduction of work performed by individuals.
- Applicability to office and individuals for planning and managing space over time is possible.
- With stowage optimizations, higher ISS utilization is possible.