University of Maryland 1856

The Institute for Systems Research

Task Scheduling for Cooperative Human/Robot Space Operations

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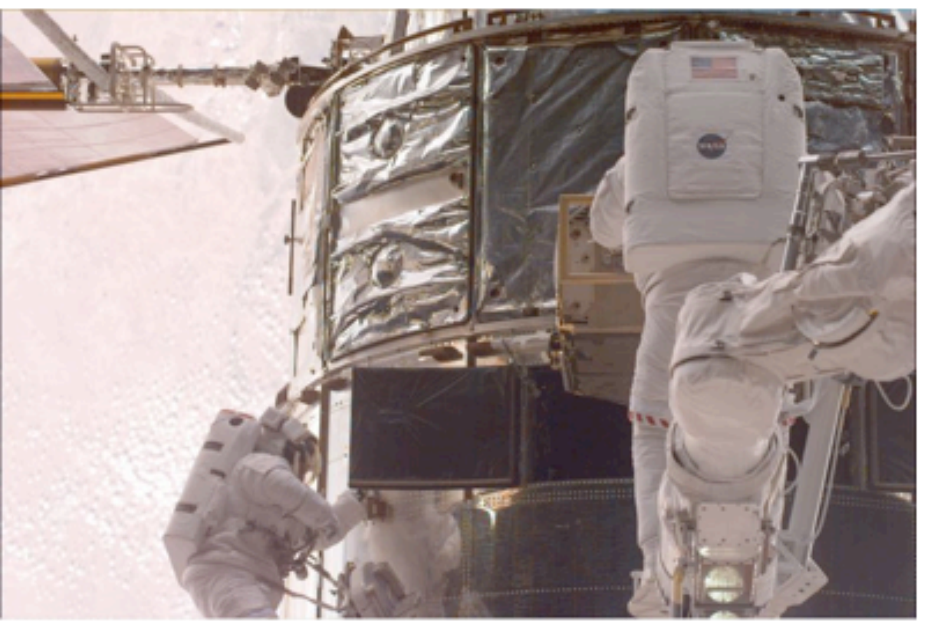
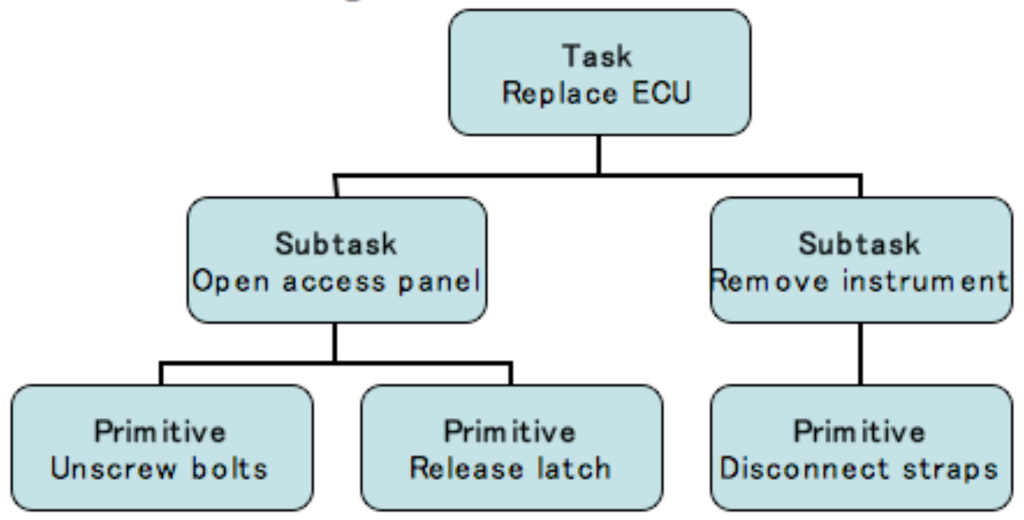


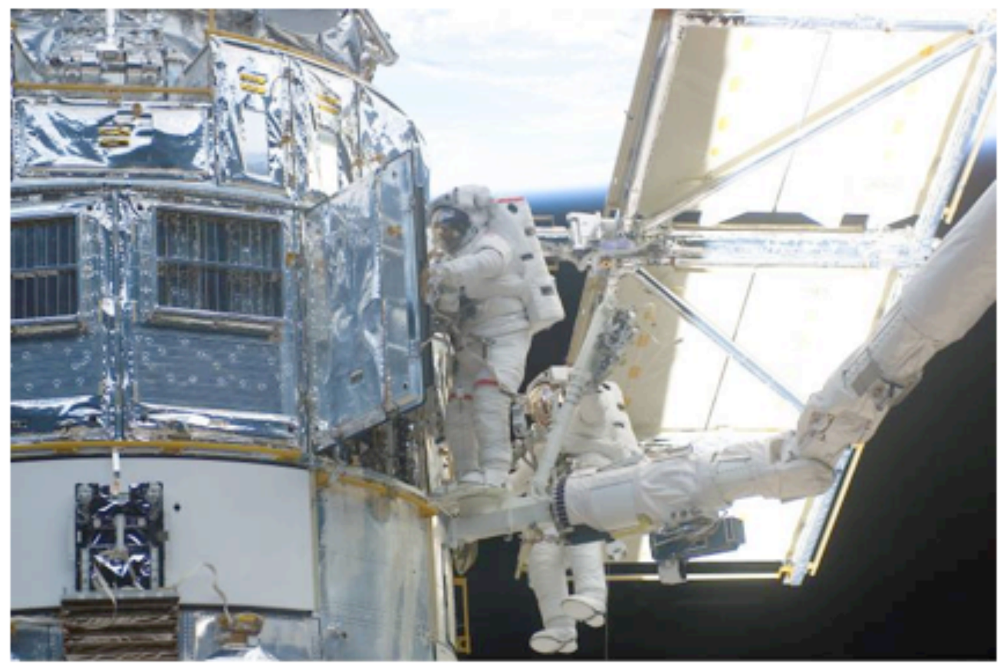
On-Orbit Servicing

- Repair of satellites and spacecraft in orbit will extend their useful lifespan
- Hubble Space Telescope was designed with access panels to allow repair of components
- Large variety in level of dexterity needed to perform servicing tasks
- EVA time is the primary constraint on task performance of the human crew

Hierarchical Task Decomposition

- Primitives for servicing activities are highly coupled
- Batch primitives by subtask for task allocation and scheduling





Benefits of a H-R Team

- Increase the volume of tasks completed
- Create more efficient and diversified operational teams

Challenges of a H-R Team

- Estimating robot performance of tasks designed for humans
- Large differences in performance capabilities and time scales of task completion
- Shared workspace considerations
- Wait time of one crew member for another

Producing a Cooperative Schedule

- Objective 1: Minimize astronaut involvement time in tasks
- Objective 2: Maximize impact of a generic robot as a supplement to the standard two human EVA crew
- Constraints: precedence constraints, relational constraints, topographical constraints, human crew time as a limited resource, robot speed

Table 1: VIK Replacement from HST SM3A

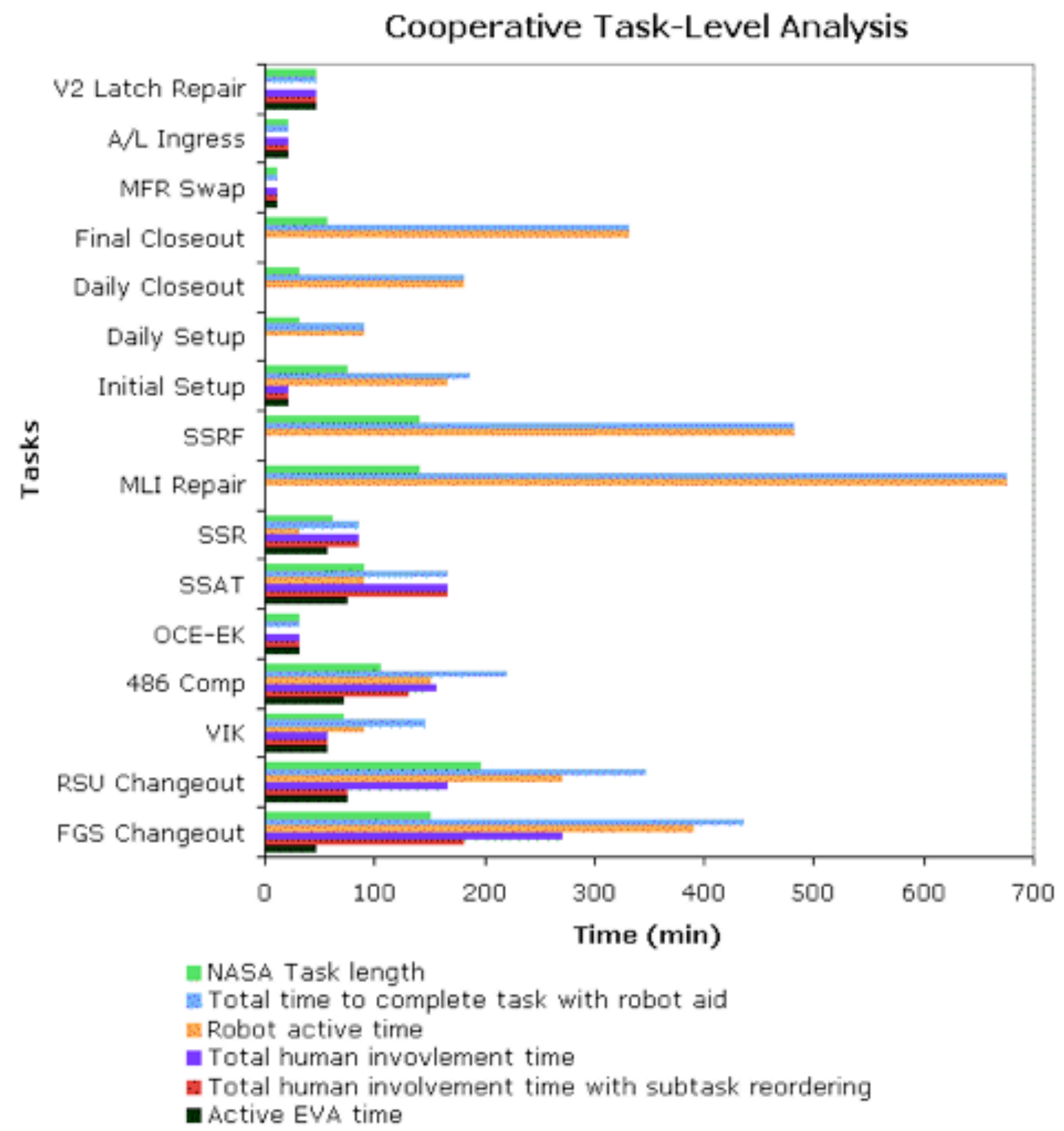
Minutes	EVA 1	EVA 2
15	VIK Retrieval	VIK Retrieval
35		VIK Bay-2 Installation
70		VIK Bay-3 Installation
NASA Task length: 70 min		

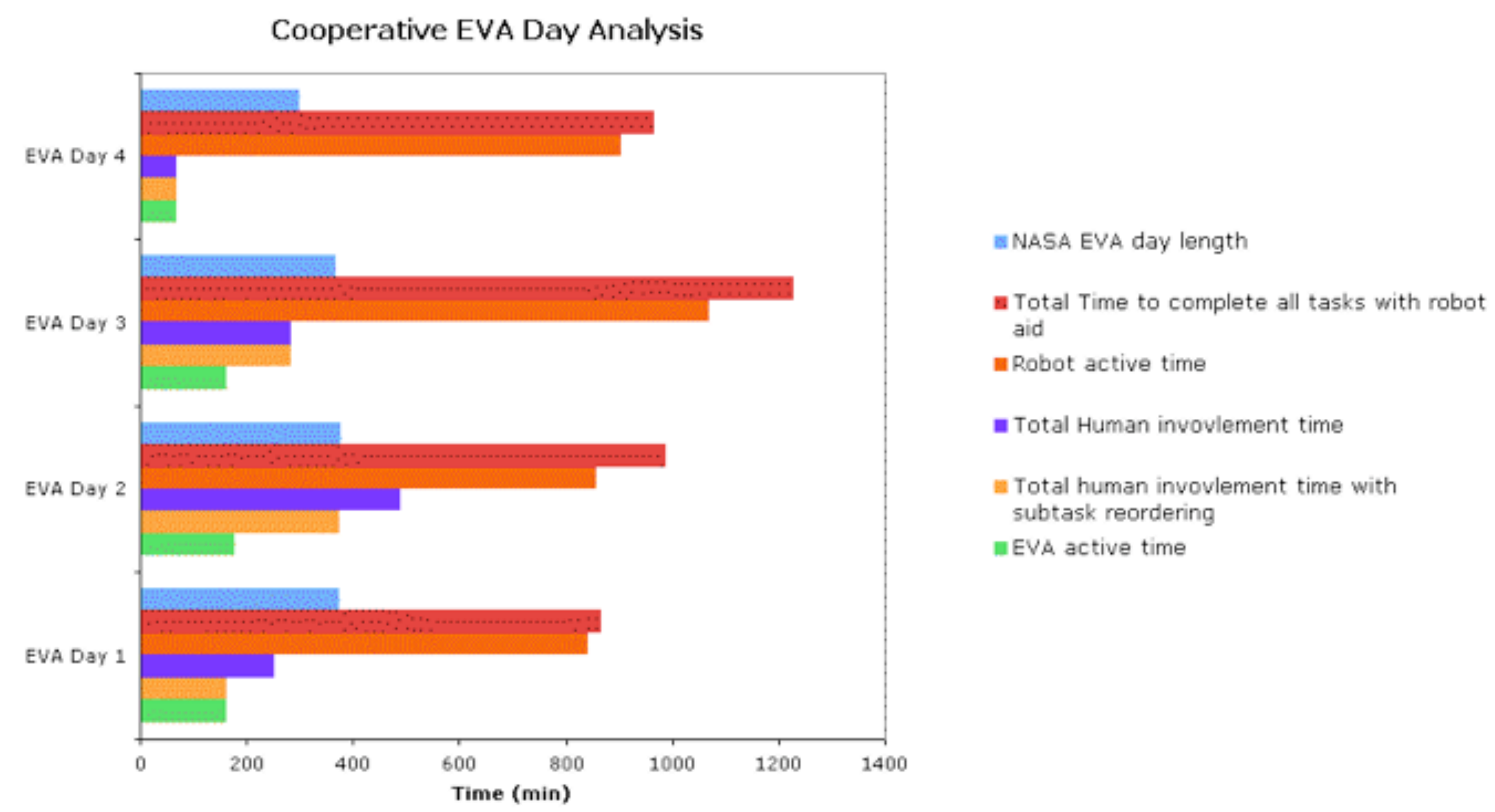
Estimating Robot Performance

- Two independent dexterous robotic arms with human reach capability
- Capable of using EVA hardware interfaces and tools
- Human subtask performance times adjusted by nominal multiplier (3x) for robot completion time estimate
- Assumed robot incapable of the fine dexterity required for electrical connectors, harnesses, and tethers

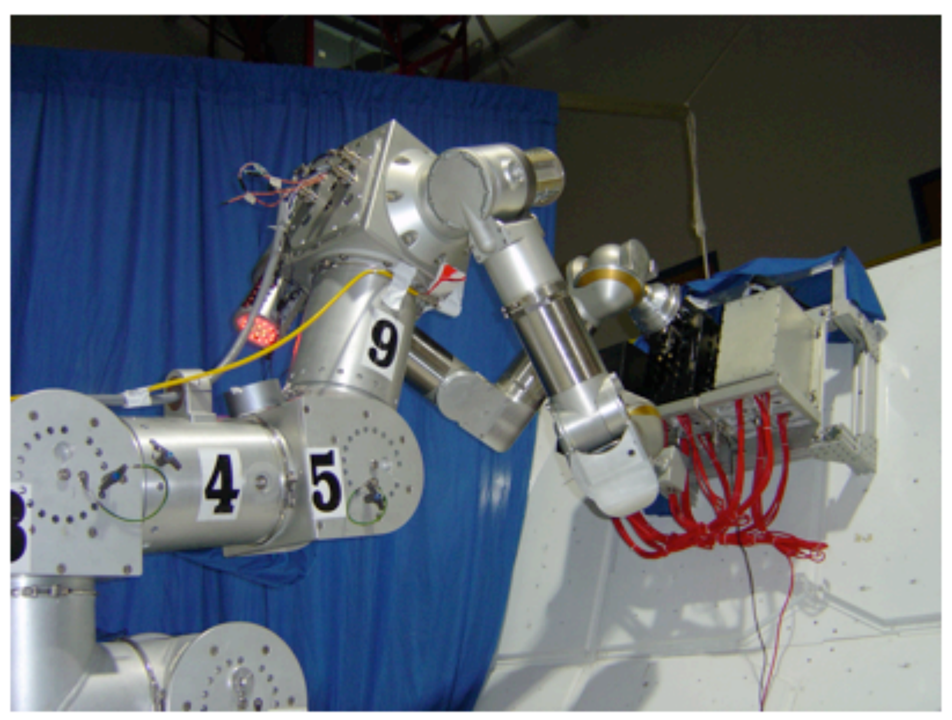
Table 2: VIK Subtasks Rearranged for Robot aid in Replacement

Minutes	EVA 1	EVA 2	Robot
90			VIK Retrieval
105		VIK Bay-2 Installation	
145		VIK Bay-3 Installation	
NASA Task length:		70 min	
Task length with robot aid:		145 min	
Active EVA time:		55 min	





- Hubble Space Telescope Servicing Mission 3A used as case study
- Total task completion time was significantly increased
- Total human crew involvement time and active time was reduced
- SM-3A tasks were completed in half the active human time of the NASA mission



Methodology for Scheduling a HR Team

- Identify primitives that must be performed by humans
- Initially allocate remaining subtasks to the robot
- Do not allow preemption
- Rearrange subtasks to shorten human involvement time in tasks
- Assess time human crew must wait for robot to perform subtasks
- Reallocate subtasks to humans if wait time is longer than human performance time

Conclusions

- Increase schedule gains by sending the humans to perform other subtasks while waiting for the robot to complete a subtask
- Under-utilization of crew (existence of downtime in timeline) allows flexibility for contingencies
- Including a dexterous robot in servicing activities will greatly increase the efficiencies of the human crew and the volume of tasks completed during future space missions
- Provides a guide to develop a better estimation of the contribution of a robot to human productivity during space mission activities