MIT
Dept of Aeronautics and Astronautics
Qualifying Exam, January 2016

Humans and Aerospace

Part I [70%] Humans and Automation Question

NASA's human research roadmap highlights the "Risk of inadequate design of human and automation/robotic integration," stating that "Given that automation and robotics must seamlessly integrate with crew, and given the greater dependence on automation and robotics in the context of long-duration spaceflight operations, there is a risk that systems will be inadequately designed, resulting in flight and ground crew errors and inefficiencies, failed mission and program objectives, and an increase in crew injuries." In future planetary exploration, human missions will be supported by rovers with varying levels of automation. ***You have been tasked with designing the manual control interface and display for a rover.*** The rover must be able to perform the tasks listed below. You should assume that the humans are nearby.

       Task List:
- Traverse an uneven terrain from point A to point B.
- Use the microscopic imager to analyze rock or soil composition.
- Collect a soil sample using a robotic arm. (You may assume that once positioned, the arm can autonomously collect the sample when activated.)
- Take pictures of geological features using a camera with an infrared filter, blue filter, or no filter.

You may make assumptions on these tasks as you create your design. Please explicitly state what assumptions you made. ***Be prepared to discuss the following questions pertaining to your manual control interface and display:***

1. How is situation awareness supported with your display?
2. Why were your chosen control interfaces selected?
3. Of the goals in the task list, discuss whether the task should be manual, supervisory, or automatic control. Describe any assumptions you made in this determination.
4. What are ways in which you could evaluate overall human-automation-robotic system performance to validate your system?

Part II –Option: Supervisory Control [30%]

Human-robot collaboration will be necessary to efficiently utilize crew time, reduce risk to crew and assets, and maximize time spent on science endeavor tasks. Propose three different architectures for multi-astronaut, multi-robot collaboration for Mars surface operations involving four crew, two rovers performing science tasks, and one heavy-lift manipulator performing assembly and maintenance tasks. Discuss advantages and disadvantages of the different architectures in terms of astronaut time on task time, robustness to loss-of-signal/communication between crew and robots, robot performance measures, human-system interaction effects (e.g. mean time to intervene for robot system as a function of level of robot autonomy), and human performance characteristics (e.g., workload, situational awareness). Your discussion should be grounded in relevant literature and studies.

Choose one of your architectures and outline the process of performing a Cognitive Work Analysis. Discuss the advantages and disadvantages of Cognitive Work Analysis versus Hierarchical Task Analysis when applied to early-stage concept design specification.

Part II—Option: Biomedical [30%]
The following questions are related to muscle mechanics.
1. Describe the relationship between muscle length and force production, as well as muscle velocity and force production. How are these curves related to muscle type?

2. What are the effects of microgravity on muscle and what are the main factors that cause these effects?

3. Describe what type of exercise should be used to maintain muscle mass based on the force-length and force-velocity curves. Which muscles should be prioritized?