The Function-Specific Level of Autonomy and Automation Tool

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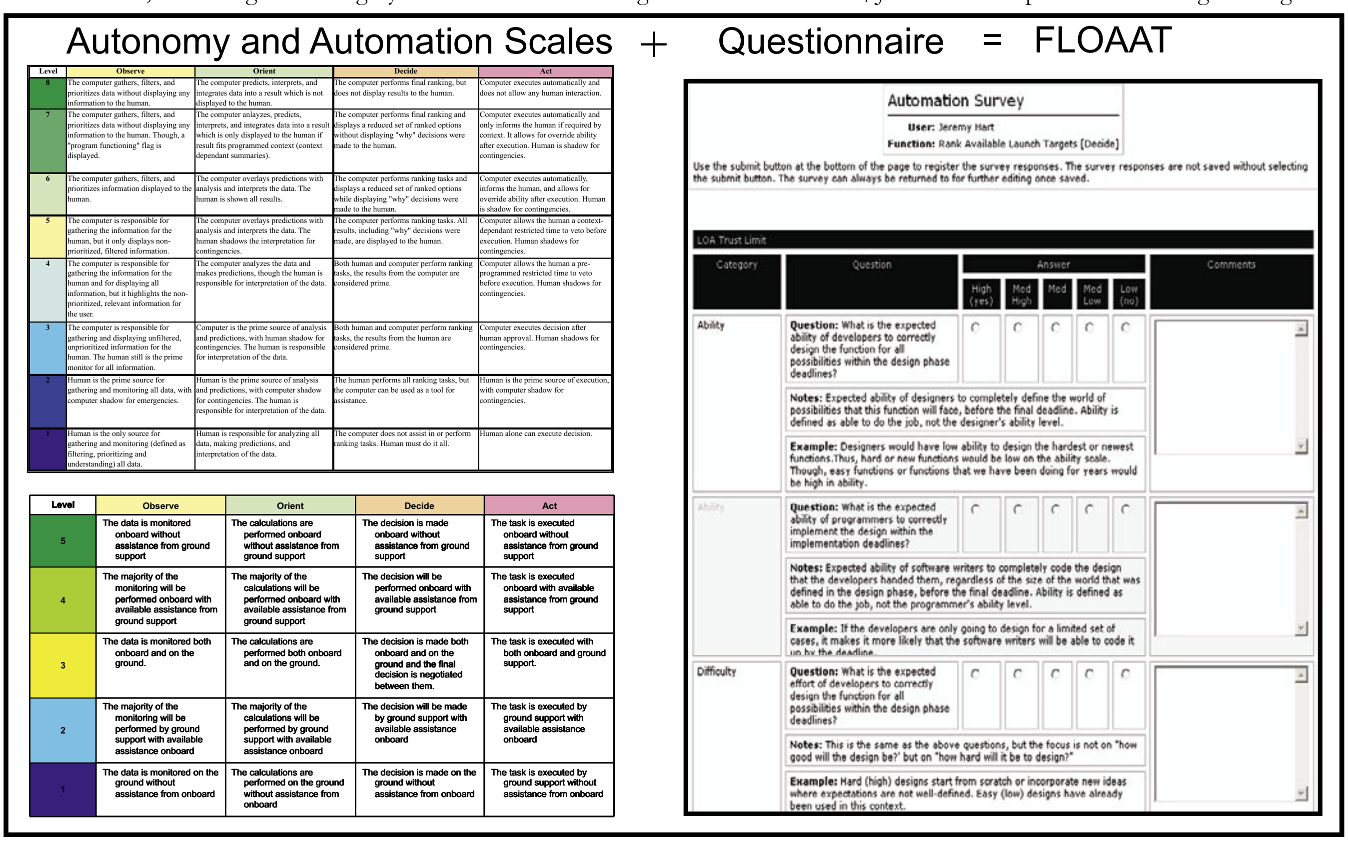
NASA's Vision for Space Exploration will significantly alter the design of the next human spaceflight vehicle. The Crew Exploration Vehicle (CEV) will be designed at higher levels of autonomy and automation than previous NASA vehicles due to: the long time lag in communications, vast computer enhancements, the emergence of highly reliable decision-making algorithms, and an increased emphasis on efficiency. At the center of this evolution in vehicle design are the questions, "What is the right balance of ground vs. onboard authority (autonomy)?" and "What is the right balance of human vs. computer authority (automation)?" To answer these questions, a team of NASA/JSC Mission Operations and Engineering



Directorate personnel have developed the Function-specific Level of Autonomy and Automation Tool (FLOAAT), as shown in the figure.

FLOAAT is a quantitative assessment tool that was originally developed for use during the design process to determine the appropriate levels of autonomy and automation to be included in the system-level requirements. It can also be used after NASA's requirements have been developed for contractor proposal evaluations by comparing contractor proposed designs to NASA's expected results. In either application, the process of using FLOAAT will result in a clearly defined, baseline balance of authority. The process uses domain-specific experts to qualitatively evaluate a set of functionally decomposed vehicle requirements using a questionnaire that yields a quantitative solution similar to the Cooper-Harper Scale or the Bedford Workload Scale. The quantitative solution maps to the set of FLOAAT Level of Autonomy and Automation Scales to provide a precise, clear, and easy-to-understand definition for the different levels of autonomy and automation. The scales show separate levels of automation and autonomy for each of the 4 stages of decision-making (Observe, Orient, Decide, and Act).

FLOAAT adapts and advances many academic and theoretical constructs into a practical application that will aide in the design of a vehicle. One important practical lesson is that users trust in the software often dictates how it is used more than software capability. This duality led us to split our tool into trust issues and cost/benefit issues. Trust issues include: software complexity, robustness, experience, understandability, art vs. science, training, etc. Cost/benefit issues include: usefulness, timeliness, criticality/safety, development costs, sustaining costs, efficiency, etc. The output from FLOAAT gives both limits for autonomy and automation based solely on trust issues and limits for autonomy and automation based solely on cost/benefit issues. The cost/benefit limit and the trust limit must be compared to find the true answer. For example, if the cost/benefit limit is higher (more automated) than the trust limit, then, even though it may be cost effective to implement an automated system at the cost/benefit limit, humans will not trust the system at that level. Since trust is the limiting factor, either the system should be automated to the trust limit or the trust issues should be resolved through test projects and education of the users until the trust limit increases to equal the cost/benefit limit.

FLOAAT has established itself as a viable technique for determining appropriate levels of autonomy and automation for crewed vehicles. FLOAAT is positioned to become the standard method for balancing human vs. computer authority and ground vs. onboard authority for vehicle design.