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Title: **Modeling, Simulation, and Experimentation for the Multi-sensor Command and Control Aircraft (MC2A)**

Suggested Track: **Modeling and Simulation** (Sessions on Adaptive Architectures for Command and Control (A2C2))

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Abstract.

Motivation:

The Multi-sensor Command and Control Aircraft (MC2A), teamed with UAVs and direct machine-to-machine connectivity to ground and space-based sensors [1], is expected to dramatically change the way future air operations, and air support to ground force operations are planned and executed. The MC2A is intended to consolidate command and control (C2), battle management (BM), intelligence, surveillance and reconnaissance (ISR), and selected information warfare (IW) functions and eventually replace elements of the current C2ISR force mix.

The MC2A, as a key battle management enabler, must cover the entire range of military operations from peacetime presence, through small-scale contingency (SSC), to major theater war (MTW). The wide range of potential Air Expeditionary Force (AEF) employment scenarios requires the MC2A to have the maximum flexibility to support everything from autonomous operations to robust deployed force packages. Each unique mission requires detailed consideration of crew positions. Some current C2 platforms (i.e., JSTARS and AWACS) perform similar missions; however, advanced technologies and fundamental increase in mission responsibility in the MC2A make direct comparisons in staff configuration and size difficult. To complete a Program Objective Memorandum (POM), the Air Force requires a basic specification of the number and type of operators needed to complete the mission.

This paper describes a quantitative Team Optimal Design (TOD) methodology to synthesize the configuration of the team to execute specific mission. The TOD model finds the number and type of operator roles for the configuration to obtain the team with optimized performance. The objective is to maximize the speed of mission execution while balancing the workload among team members, provided the workload threshold and organization cost constraints are satisfied.

Problem:

The functions and capabilities required by MC2A include, but are not limited to, the following [3]:

- Battle Management: attack support; retasking of aircraft and sensors for TCT, status monitoring, search and rescue, situation awareness to air and ground forces, etc.
- Surveillance and Reconnaissance: detecting, identifying and tracking ground, airborne and maritime objects; cueing other ISR sensor systems; information/intelligence fusion, etc.
- Mission Planning: planning of air and ground operations to execute the ATO, etc.
- Information Warfare: prevent or limit the effective use of the electromagnetic spectrum and support other electronic warfare operations.
- Intelligence Support: managing sensor collection, responsive target analysis and combat assessment, providing indications and warning (I&W) and SA.
- Communications: managing interfaces of data link, voice communications, ground stations and remote interoperability coordination.

Until the MC2A is fully operational, current combat capability must be maintained. The complete replacement of current legacy airframes may not be required and/or necessary, but must be weighed against the additional life cycle cost of keeping them in the inventory. A thorough engineering analysis and an analysis of alternatives (AoA) is required to determine the optimum mix and configuration of sensors and platforms with emphasis on technology risk, lifecycle costs, and concepts of employment.

In this paper, we present the methodology to design the optimized manning for MC2A given the operational concepts and required capabilities, provided the team decision-making, expertise, and operational cost constraints are met. Our design approach allows specification of team configurations for efficiently operating MC2A to execute mission scenarios of various contingencies.

Method:

In order to analyze and simulate the operations of MC2A, we conducted mission decomposition to define functional responsibilities for the MC2A within the context of an operational mission. Fig. 1 shows the core responsibilities of the MC2A. Working with subject matter experts, we developed functional process flows of MC2A by decomposing each stage into representative functions (i.e., see Fig. 2 for decomposition of "Direct execution of and conduct dynamic air and space operations" function). Each of these functions is in turn decomposed into high level task responsibilities.

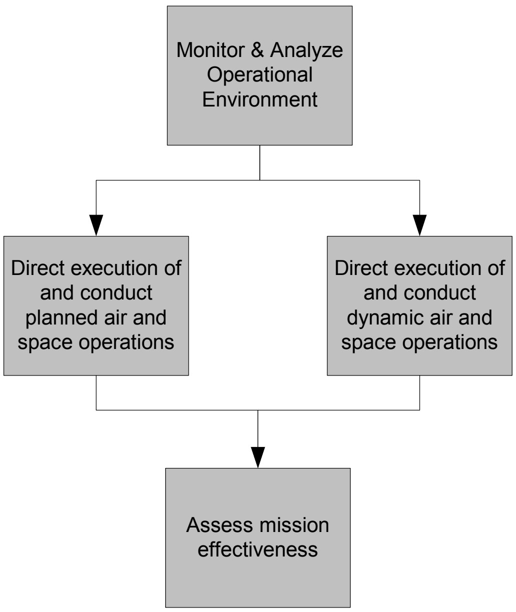

Figure 1: Overview of MC2A Functions

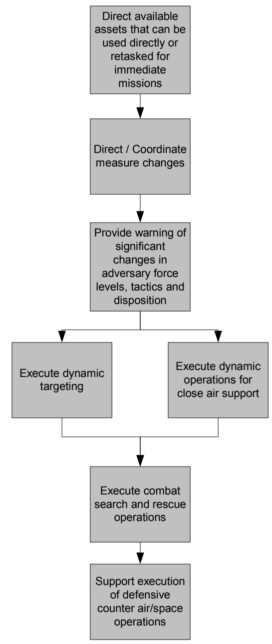

Figure 2: Functional decomposition of "Direct execution of and conduct dynamic air and space operations" function

When decomposition of MC2A functions into tasks is obtained, we create mission scenarios for various contingencies. The operational content of these missions was provided to the project team by the Theater Aerospace Command and Control Simulation Facility (TACCSF) at Kirtland AFB and is based on their core simulation for Desert Pivot and Virtual Flag exercises. These scenarios are represented as a collection of events, with each event defined as a directed graph of tasks with precedence/information flow constraints. The task attributes are defined, which include task duration and workload. The precedence among tasks in the event graph constrains the task execution: all predecessor tasks must be completed before the successor task execution may start. The precedence arcs among tasks also identify the information flow requirements: the precedence links are weighted with the delay associated with transferring the information from agent assigned to predecessor task to the agent assigned to successor task. This delay is equal to 0 when task are assigned to the same team member.

In MC2A experimentation, we utilized Team Optimal Design (TOD) methodology to create the optimal team configuration for specified scenarios. The configuration consists of human agents and the specification of their roles. The TOD methodology addresses the problem of finding the optimal allocation (scheduling) or *mapping* of tasks with precedence and information flow requirements to organizational members while satisfying various constraints. The objective function is to maximize the speed of mission execution. The output of the TOD model is a tentative assignment of tasks to team members that allows predicting the workload levels and dynamic operational characteristics of simulated team. Consequently, the sensitivity analysis can be conducted to vary the number and type of operational roles for the configuration to obtain the team with optimized performance given constraints on resources and cost of organization. In TOD, the sensitivity analysis is conducted based on optimization of estimated "marginal" workload. The flow chart of our modeling methodology is outlined in Fig. 3.

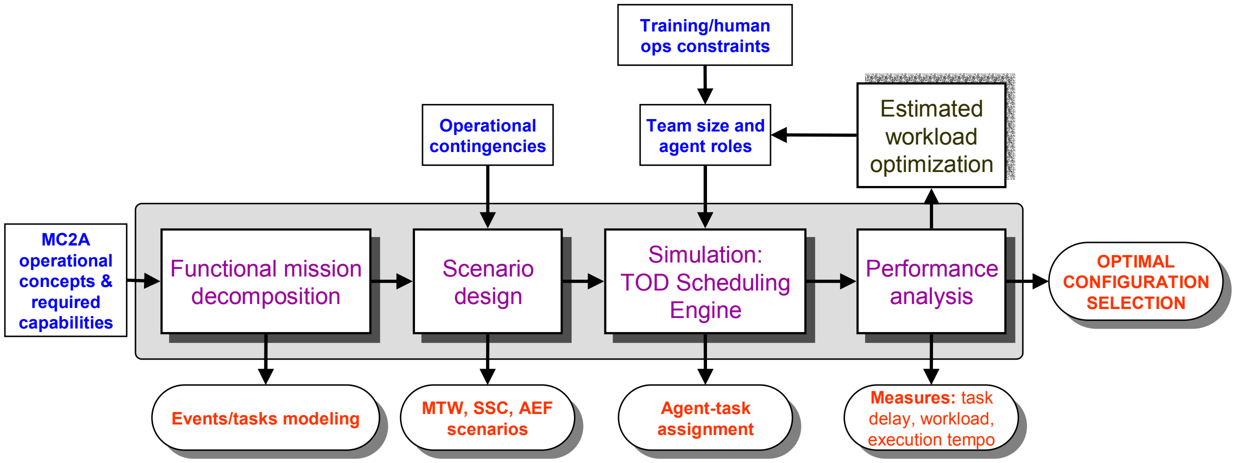

Figure 3: Flow chart of TOD modeling and simulation for MC2A

Results and Conclusions:

In this paper, we present concepts of modeling and simulation that laid the ground for the design of optimized MC2A team configuration. The primary contributions of this paper are:

- Modeling of MC2A operational stages, which included function/task decomposition of component process flows;
- Design of mission scenarios for various contingencies;
- TOD methodology for the design of project-based teams;
- Analytic team build-up for sensitivity analysis using optimized estimated workload;
- Redesign of agent roles based on simulated mission execution and team training constraints;
- Specification of optimized team configurations for scenarios of various contingencies; and
- Comparative analysis and evaluation of simulated teams using average task delay, workload distribution, and execution tempo measures.

The analytic methods, applications, and measures illustrated in this paper form the basis for current research on organizational design for large-scale human-machine systems.

References.

[1] R. Landry. "Networking for the MC2A", Unpublished PowerPoint presentation, September, 2002.

[2] USAF. "Multi-Sensor Command and Control Functionality", Initial requirements document, HQ USAF/XORI, draft, August 08, 2002.

[3] R. Whitaker, B. Pfeiffer, E. Walby, G.F. Perryman. "Concept of Operations for the Multi-Sensor Command and Control Aircraft", Aerospace C2 & ISR Center, executive summary, 2002.