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Chair of Spacecraft Systems

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Master's Thesis Opportunity
Chair of Spacecraft Systems (SPS)
Department of Aerospace and Geodesy
Technical University of Munich

Agentic AI for Concurrent Conceptual Design of Space Systems: An Experimental Framework for Multi-Agent Collaborative Engineering

Supervisor

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1. Context and Motivation

Concurrent Conceptual Design (CCD) is a well-established methodology employed by space agencies and industry to rapidly explore feasible design solutions for complex missions. In a typical CCD session, a multidisciplinary team of domain experts works simultaneously and iteratively, converging on a preliminary spacecraft design within days rather than months. The European Space Agency's Concurrent Design Facility (CDF), and analogous facilities worldwide, have demonstrated the effectiveness of this approach over decades.

Recent advances in agentic AI systems open a compelling new research direction: can multi-agent AI systems autonomously replicate or augment the concurrent design process? Agentic AI refers to AI systems capable of autonomous reasoning, planning, tool use, and collaborative interaction without continuous human oversight. The emergence of capable large language models, combined with frameworks for multi-agent orchestration, tool integration, and structured decision-making, makes it now technically feasible to investigate this question with scientific rigor.

2. Thesis Objectives and Research Questions

The objective of this Master's thesis is to design, implement, and experimentally evaluate a multi-agent AI system capable of executing a concurrent conceptual design study for a space mission. The system shall be benchmarked against real concurrent design study outputs to assess the quality, credibility, and completeness of agent-generated results.

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3. Methodology

The thesis will follow a structured experimental approach organized around four work packages:

WP1: Agentic Infrastructure Development. Design and implement a reproducible multi-agent architecture for concurrent spacecraft design. Each agent shall represent a domain specialist (e.g. systems engineer, power subsystem engineer, AOCS engineer, thermal engineer, communications engineer, payload specialist, mission analyst). The infrastructure shall support: (i) agent-to-agent communication via structured message passing; (ii) integration with parametric engineering tools such as Valispace or an equivalent open infrastructure developed by the student; (iii) a shared design repository for iterative convergence; (iv) logging of all agent interactions, reasoning traces, and design decisions for post-hoc analysis. The entire stack shall be version-controlled and containerized to ensure reproducibility, following best practices identified in the evaluation of agentic AI systems.

WP2: Multi-Agent Collaboration Protocols. Implement and test at least three collaboration paradigms. For the agentic Delphi survey, the student shall implement multi-round anonymous estimation and convergence mechanisms following the classical Delphi structure. For expert panel discussions, the student shall implement structured debate protocols with role-specific argumentation. For group decision-making, the student shall implement negotiation protocols with explicit constraint propagation and trade-off resolution. The value of each paradigm shall be characterized through numerical simulation campaigns, varying the number of agents, the degree of agent specialization, the number of interaction rounds, and the complexity of the design problem.

WP3: Case Study and Benchmarking. Apply the developed framework to an Earth Observation mission case study. The case study shall be selected to allow direct benchmarking against the output of a real concurrent design session. The student shall execute the agentic design process multiple times (Monte Carlo approach) to characterize the statistical distribution of design outputs and assess convergence, consistency, and sensitivity to initial conditions.

WP4: Evaluation and Effectiveness Metrics. Develop a structured evaluation framework that includes quantitative metrics (deviation from benchmark budgets, requirements completeness, design consistency, computation time, cost of API calls) and qualitative metrics (design rationale quality, novelty of explored design points, identification of design drivers). Assess whether the agentic approach can serve as a credible augmentation or partial substitute for human-led concurrent design sessions, and under what conditions.

4. Expected Deliverables

The student is expected to deliver the following: (1) a fully documented and reproducible open-source agentic engineering stack, containerized and version-controlled; (2) a detailed experimental campaign with statistical analysis of agent-generated design outputs; (3) a comparative benchmarking study against a real concurrent design session for an Earth Observation mission; (4) a characterization of the effectiveness of different multi-agent collaboration paradigms (expert panel, Delphi survey, group decision-making); (5) a set of best practices and guidelines for configuring and operating agentic engineers in a concurrent design context; and (6) a Master’s thesis document reporting all methods, results, and conclusions.

5. Candidate Profile

The ideal candidate is a Master’s student in Aerospace Engineering, Systems Engineering, Computer Science, or a related discipline with the following qualifications: interest in developing or strong skills in agentic AI (OpenClaw,) and generative AI. Strong programming skills in Python; experience with LLM APIs and agent frameworks such as LangChain, CrewAI, AutoGen, or similar is highly desirable; familiarity with spacecraft systems engineering fundamentals (orbit mechanics, subsystem sizing, mission analysis); understanding of concurrent engineering or model-based systems engineering concepts; interest in AI, large language models, and autonomous systems; ability to design and execute rigorous numerical experiments with statistical analysis; and fluency in English (written and spoken).

Contact and Application

Interested candidates should send their CV, transcript of records, and a brief statement of motivation to Prof. Dr. Alessandro Golkar at golkar@tum.de. Please include “MSc Thesis: Agentic Concurrent Design” in the subject line.