CAREER: Theoretical Foundations of the UAS in the NAS Problem (Unmanned Aerial Systems in the National Air Space)

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Key Problems Addressed:

* **airspace-wide reasoning (NAS):** enabling design-time analysis of fleet-wide properties, scalable open-environment verification strategies
* **on-board the UAS:** real-time, on-board system health management for intelligent monitoring, mitigation triggering
* **theoretical foundations:** algorithmic advances for scalability, optimizations for real-world verification problems

Solutions:

1) in the environment (NAS): new symbolic model checking based algorithms for *design spaces* (multiple properties, multiple models)

2) underlying theory enabling their formal analysis: algorithmic improvements for IC3-based symbolic model checking techniques

3) on-board the UAS: specification elicitation and on-board, embedded-system runtime verification tailored to limited resources

Scientific Impact:

* Analyzed a design space of over 20,000 designs for the NextGen air traffic control system [GCMTR16]
* FuseIC3, an algorithm for ehecking large design spaces, is on average up to 5.48 (median 1.75) faster than checking each model individually, and up to 3.67 (median 1.72) faster than the state-of-the-art incremental IC3 algorithm. [DR17]
* Satisfiability checking algorithms for Mission-Time LTL [LVR19], and LTL_f [LZPRV19]; limited resource RV for MLTL [KZJZR20]

Broader Impact (impact on society):

* Algorithms and methods used by practitioners/system designers for other systems (UTM, sounding rocket)
* Algorithms extended by others, e.g., D^3 algorithm to probabilistic verification, reactive synthesis domains

Broader Impact (education and outreach): OpenUAS Team

* 16 undergraduate researchers (diverse team)
* Designing accessible (cost, materials, construction), open-source all-COTS/3D-printable fixed-wing, reconfigurable, customizable UAS testbed for high schoolers to researchers
* First successful test flight series + first publication (12 undergrad authors) in IEEE's ICUAS 2021 "OpenUAS Version 1.0"

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