A 3D Simulation Platform for Decentralized Decision-Making in Advanced Air Mobility

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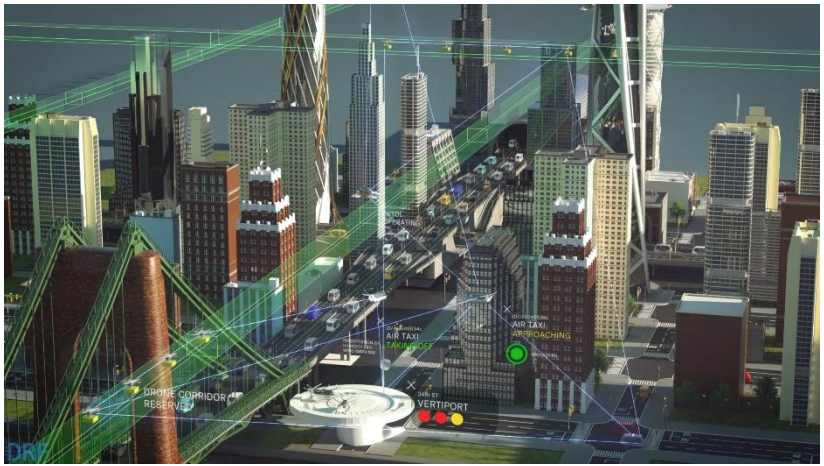
Motivation

Key characteristic of future urban air mobility (UAM) management:

- High demand for decision
- Commercial interest consideration
- Sharing of airspace for different UAM tasks
- Increased use of artificial intelligence (AI)
- Human oversight on machines



Research Goal

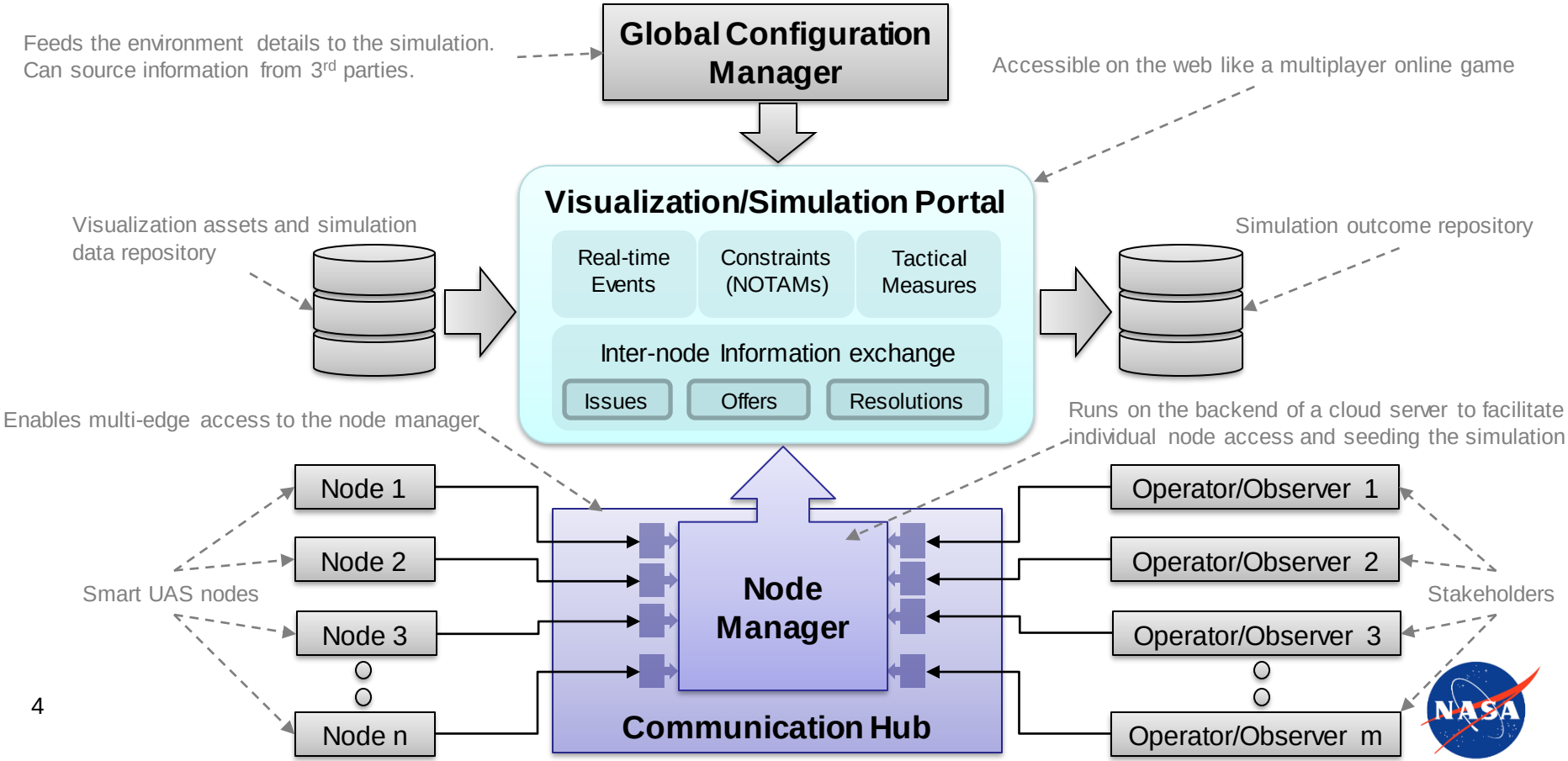
To offer a simulation platform to the UAM stakeholders, aiding:

- Assessment of future aviation technologies and resources
- Immersive visualization of shared airspace operations and interpretation of AI actions driven by complex models
- Establishment of machine-centric UAM traffic management with human oversight and insight

Value Adds

- Researchers
  - *For bringing new technology to field quickly*
- UAS Operators
  - *For optimizing business operation*
- City Authorities
  - *For planning air ways and schedules*
- Traffic Managers
  - *For assessing demand criticality and shared decision making in airspace operations*

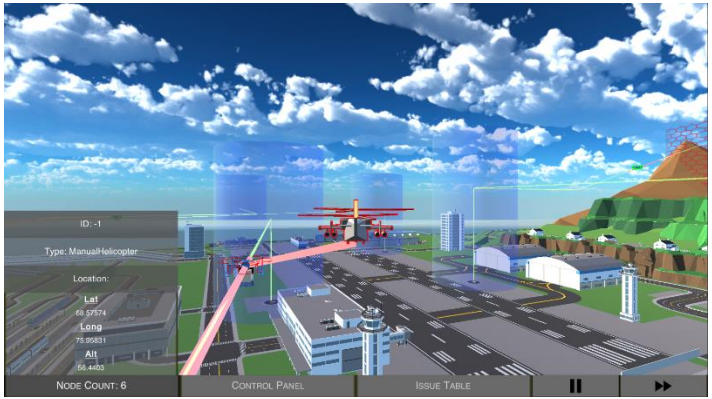
Software Architecture



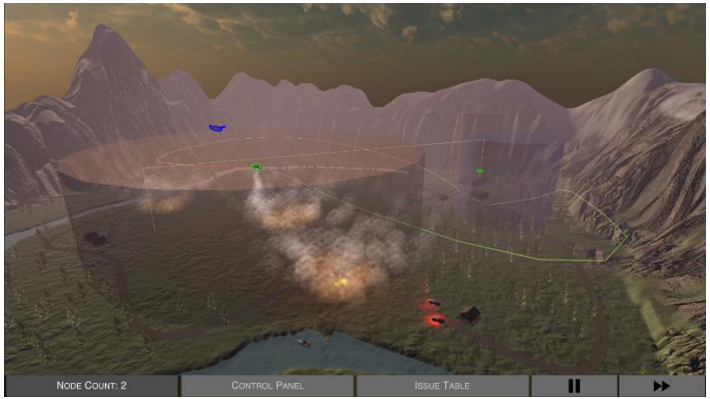
Simulation Environment

Launch Page

Scene Selection Page

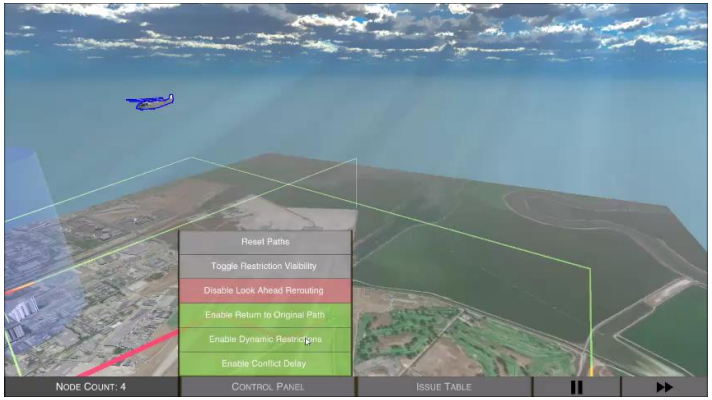


Urban Mobility Scenario

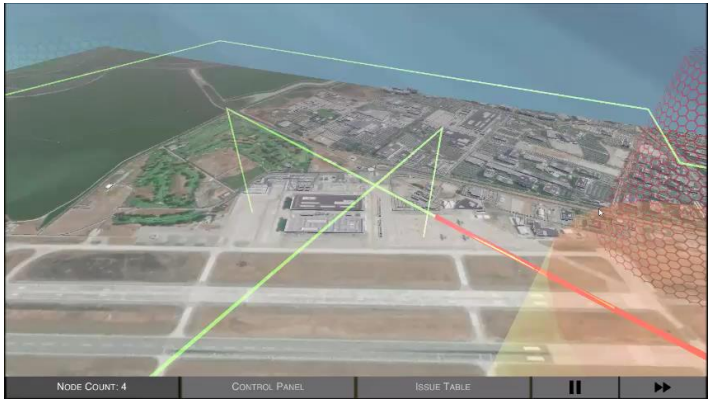


Wildfire Scenario

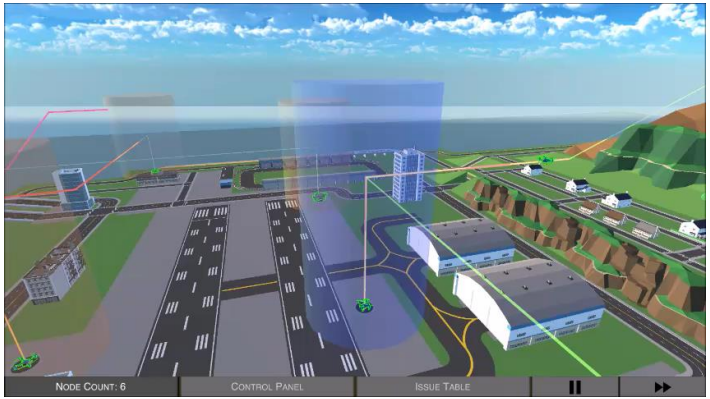
Platform Features



Dynamic Restrictions



Tactical Deconfliction



Single-pad Vertiport Access

First-person Perspective Views and Flight Control

Distributed Decision Making Example

Issue table:

	Node 1	Node 2	…	…	Node N
Node 1		80	0	0	0
Node 2	78		0	0	0
…	0	0		$^{Cx}t_{ij}$	0
…	0	0	$^{Cx}t_{ji}$		0
Node N	0	0	0	0	

$^{Cx}t_{ij}$: *Time to conflict 'x' between node i and node j as determined by node i.*

$U_{1\ to\ l}$: Strategy utilization cost for conflict avoidance
$P_{1\ to\ m}$: Accessible parameters that are related to the execution of the strategies
$Q_{1\ to\ n}$: Private parameters that are related to the execution of the strategies
W_{ij}: Business preference to alter the parameter P_i for strategy S_j
r: Smart agent id (1 to N)
Δ: Uncertainty in estimating other nodes' business weight preference
φ: Uncertainty in estimating other nodes' private parameters used in utilization cost
μ: Conflict status, $^{g}U_k$: Global reward, $^{t}U_k$: Time penalty

$$
\begin{aligned}
&{}^{r}U_k \\
&= \left[\sum_{i=1}^{m} \left({}^{r}P_i \cdot {}^{r}W_{ki} \right)_{norm} + \sum_{j=1}^{n} \left({}^{r}Q_j \cdot {}^{r}W_{kj} \right)_{norm} \right] \\
&- \left[\sum_{s=1}^{N} \mu_{rs} \cdot \left(\sum_{i=1}^{m} {}^{s}P_i \cdot \left({}^{s}W_{ki} + \Delta\ {}^{s}W_{ki} \right) + {}^{s}\varphi_{kj} \right) \right] \\
&- {}^{g}U_k + {}^{t}U_k
\end{aligned}
$$

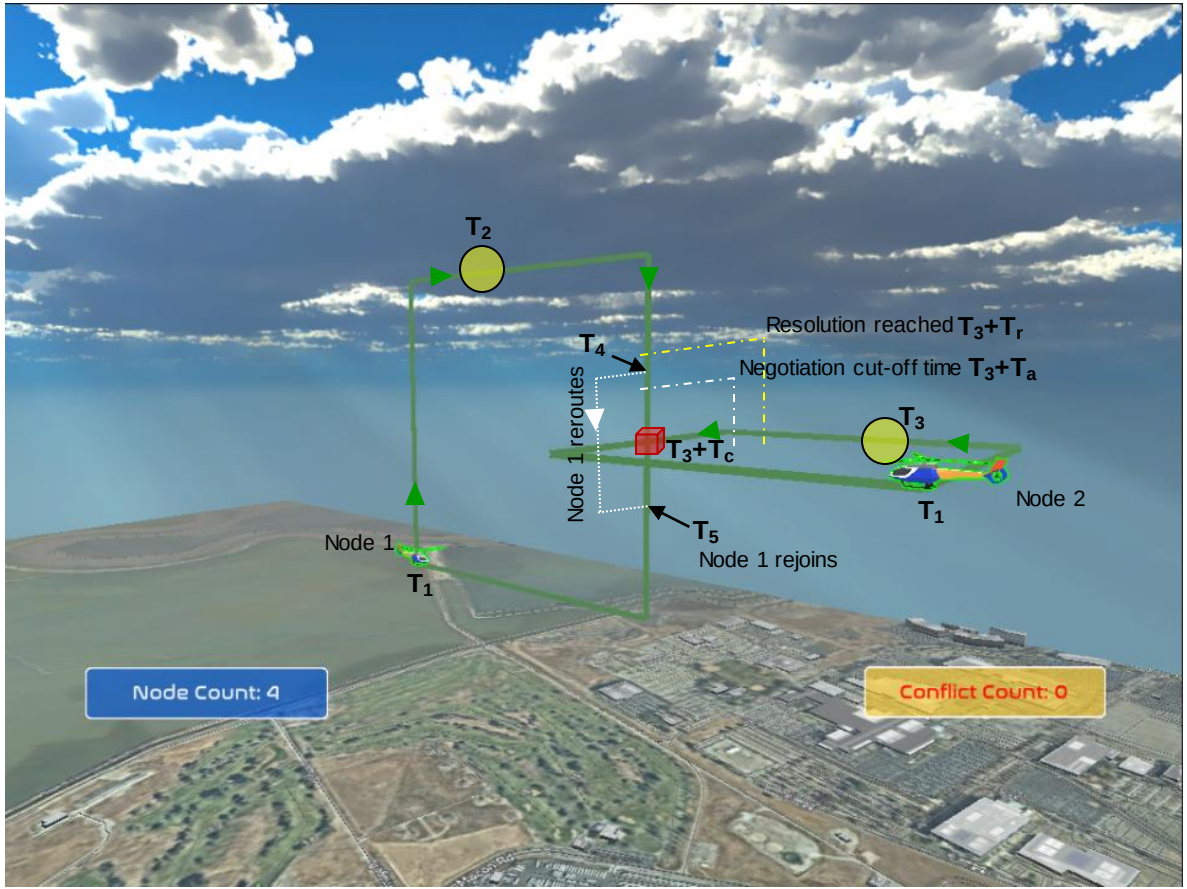
Strategy table:

Strategy	Node 1	Node 2	…	Node N
S_1	$^{1}U_1$	$^{2}U_1$	…	$^{N}U_1$
S_2	$^{1}U_2$	$^{2}U_2$	…	$^{N}U_2$
…	…	…	$^{r}U_k$	…
S_L	$^{1}U_L$	$^{2}U_L$	…	$^{N}U_L$

Issue	Time	Action	Outcome
$^{Cx}t_{ji}$	20210608-115528	$^{i}S_1{}^{j}S_0$	Pass
$^{Cy}t_{ji}$	20210608-082015	-	Fail

- A. Das, K. Marotta and H. Idris, "AEGIS: Autonomous Entity Global Intelligence System for Urban Air Mobility," in *AIAA Aviation*, 2020.
- A. Das, K. Marotta and H. Idris, "Deep Learning-based Negotiation Strategy Selection for Cooperative Conflict Resolution in Urban Air Mobility," in *AIAA SciTech*, 2021.

Strategic Deconfliction through Negotiation



T_1: Nodes following planned trajectories

T_2: Node 1 detects conflict with node 2

T_3: Node 2 detects conflict with node 1

$T_3 + T_c$: Est. time at which conflict occurs

$T_3 + T_a$: Time set as cutoff for negotiation

$T_3 + T_r$: Time at which resolution found

T_4: Node 1 reroutes as per the agreement

T_5: Node 1 rejoins the planned route

Strategic Deconfliction via Negotiation

Key Takeaways

- A general-purpose, modular, 3D simulation platform for AAM
- Holistic visual interpretation of AI-driven interactions
- Decentralized decision making
- Human-centric to machine-centric airspace management
- Hub for Community data