Planning and Implementation of Emerging Advanced Ariel Mobility

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TRB Executive Committee Policy Session
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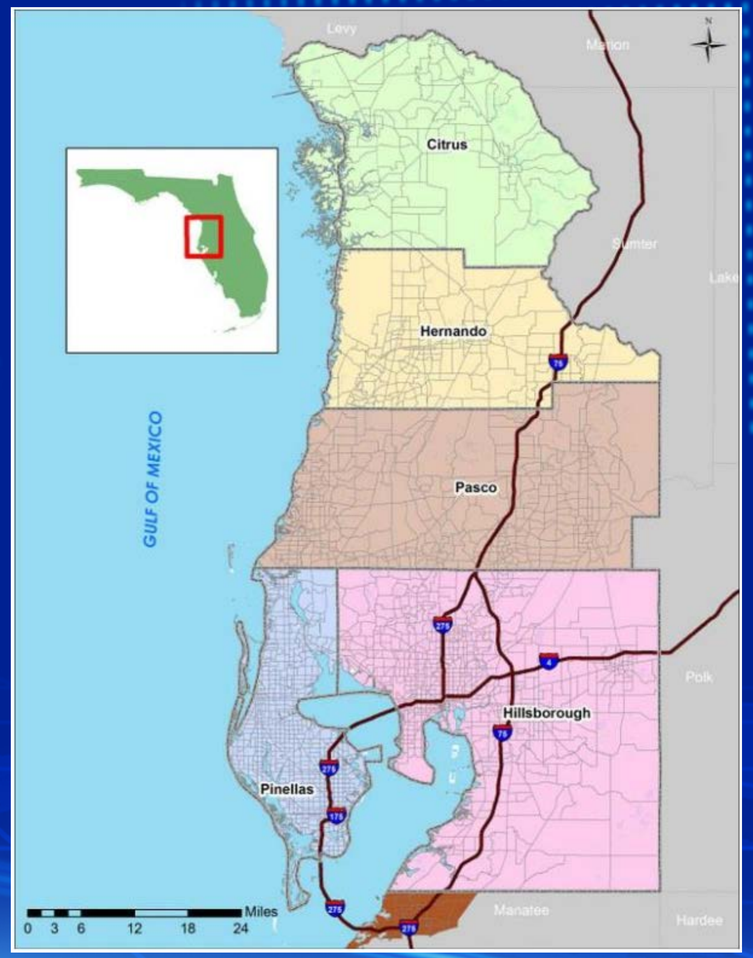
Road Map

- Network design of Urban Air Mobility considering mode competition
- Policy questions and discussion of landside infrastructure and market entrance of AAM
- Trajectory planning of high-density operations for automated traffic management of AAM
- Policy question and discussion of airspace design and traffic management of AAM

Network Design of UAM Considering Node Competition

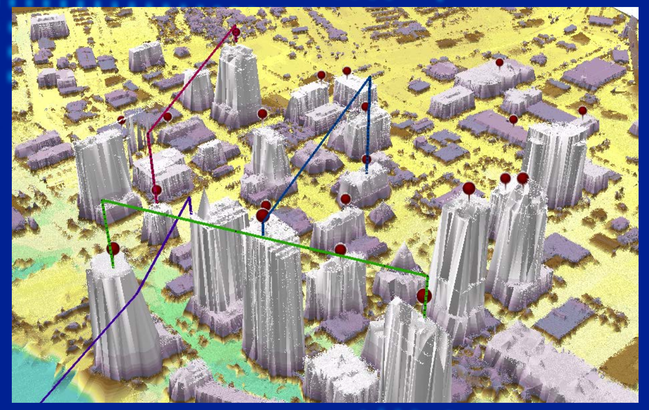
Problem Statement

Given a metropolitan area, how many vertiports are needed and where they should be located to attract the most of potential users considering the competition from other modes? (City Planners, UAM Service Providers)



Tampa Bay Regional Planning Model Study Area

Solution Method



- Generate 3-D map from LIDAR data to obtain the candidate locations of vertiports: Rooftop, parking lot, open space ……

- Mathematical modeling of network design and travel mode choice as a single location hub-and-spoke problem

Network Design

Vertiport Placement
Budget limit and **spatial requirement** for eVTOL aircraft operation restrict available locations and number of vertiports.

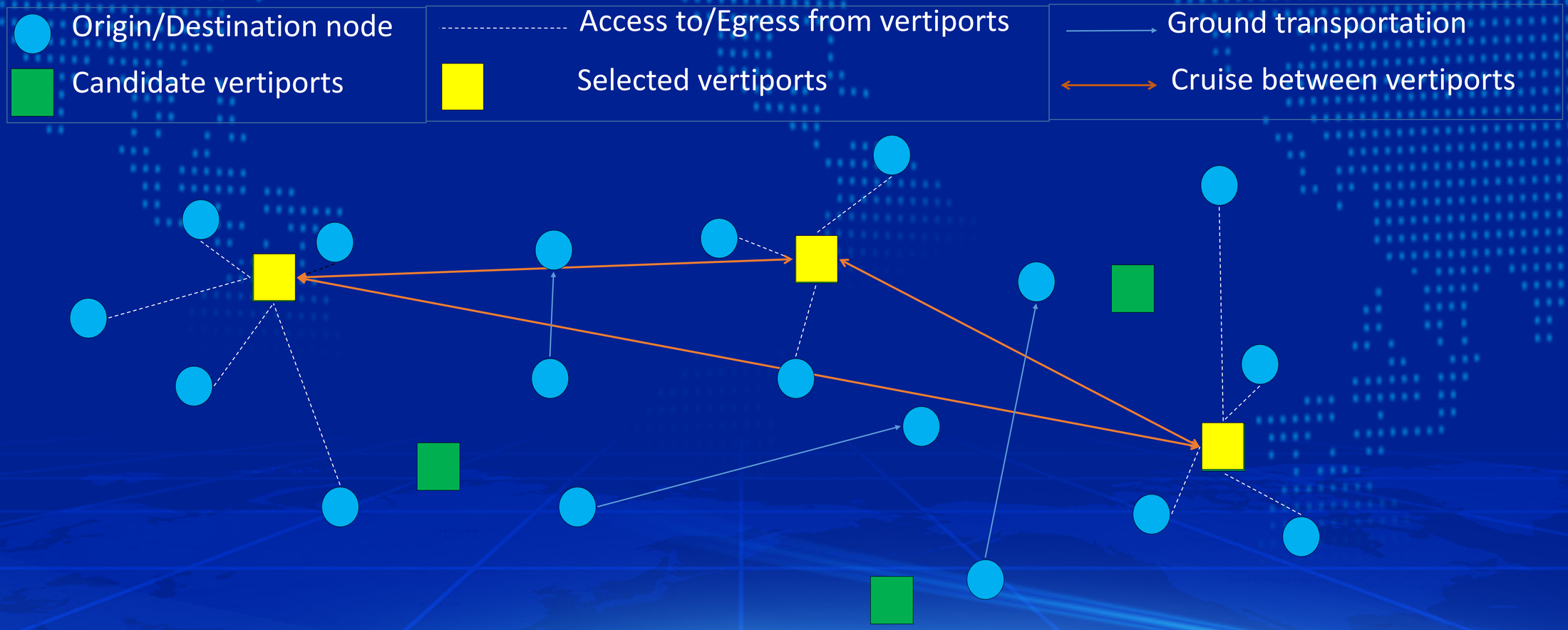
User Allocation
UAM service involves **multimodal trips**: ground trip access to or egress from vertiports and air trip between vertiports. Each user will always select route with minimum travel time。

Travel Mode Choice

Price & Time Tradeoffs
Compared with pure ground transportation, commuting through eVTOL aircrafts can greatly reduce **travel time** with higher **travel cost.**

Value of Time
As long as the ratio of reduced travel time to increased travel cost is smaller than users' value of time, they will use UAM service.

Single Allocation Hub-and-Spoke Network



Single Allocation Hub-and-Spoke Network Illustration

Case Study – Tampa Bay Region

$$\min \sum_{p\in P}\left\{(t^p * \gamma^p + c^p) * z^p + \sum_k \sum_{d\neq k}(c_{kd} + (t_{kd} + t_{tw} + \sum_a \sum_k g^p_{ak}(t^p_{ak} * \gamma^p + c^p_{ak}) + \sum_e \sum_d h^p_{ed}(t^p_{ed} *\right.$$

Minimize total generalized cost (travel cost + monetarized travel time)

$s.t.$

$\sum_k y_k = u,\ \forall k \in M$

$z^p + \sum_k \sum_{d\neq k} x^p_{kd} = 1, \forall\, p \in P$

$\sum_{d\in M, d\neq k} x^p_{kd} + \sum_{d\in M, d\neq k} x^p_{dk} \leq y_k, \forall k \in M, \forall\, p \in P$

Hub-and-spoke modeling structure: limit the number of vertiports, travelers will select between UAM service and pure ground trip and restrict each UAM trip transferred through selected vertiports.

$\sum_k \sum_{d\neq k} x^p_{kd} = \sum_a \sum_k g^p_{ak}\,; \sum_k \sum_{d\neq k} x^p_{kd} = \sum_e \sum_d h^p_{ed}\,, \forall p \in P$

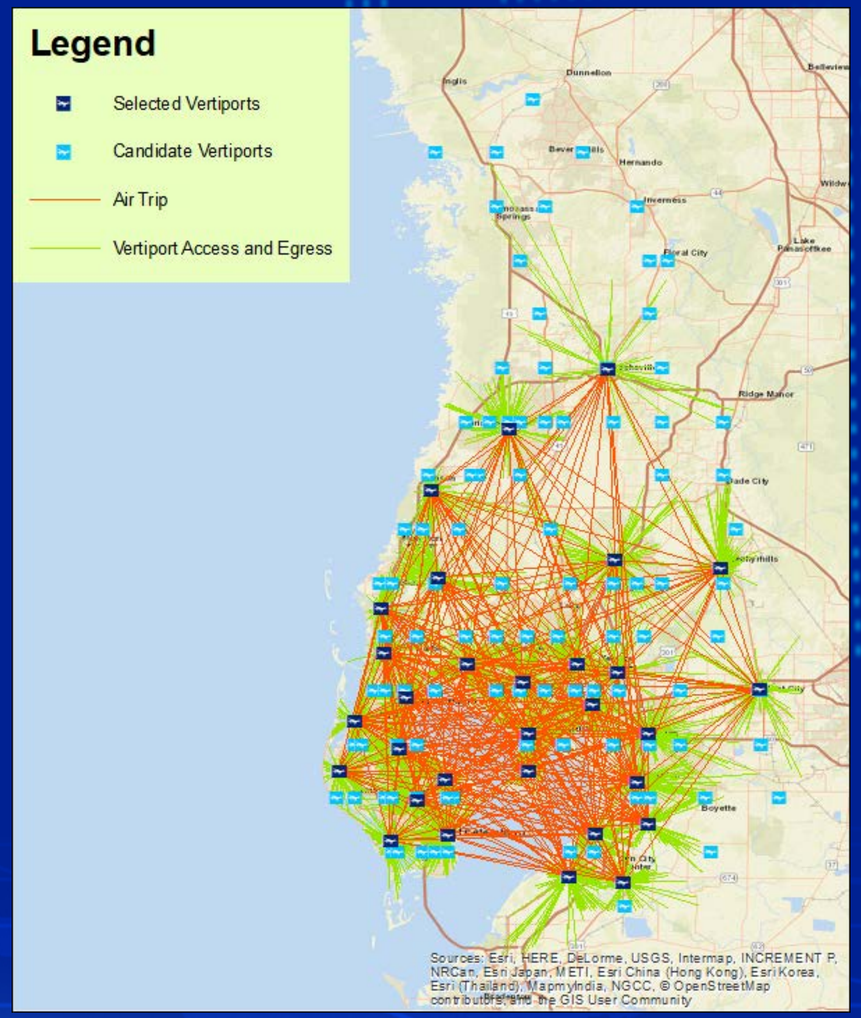
$2x^p_{kd} \leq \sum_a g^p_{ak} + \sum_e g^p_{ed}\,, \forall k, d \neq k \in M, \forall p \in P$

Restrict relations between UAM selection and vertiport access/egress mode choice.

$[t^p - \sum_k \sum_{d\neq k}(t_{kd} + t_{tw} + t_{tl}) * x^p_{kd} - \sum_a \sum_k g^p_{ak} t^p_{ak} - \sum_e \sum_d h^p_{ed} t^p_{ed}] * \gamma^p \geq \sum_k \sum_d c^p_{kd} * x^p_{kd} + \sum_a \sum_k g^p_{ak}\, c^p_{ak} + \sum_e \sum_d h^p_{ed} c^p_{ed} - c^p, \forall p \in P$

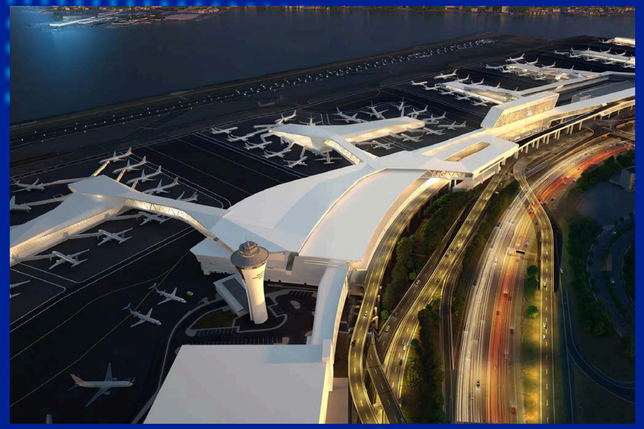
Users will only adopt UAM service if value of saved travel time is larger than the additional cost.

$z^p \in \{0,1\}, y_k \in \{0,1\}, x^p_{kd} \in \{0,1\}, g^p_{ak} \in \{0,1\}, h^p_{ed} \in \{0,1\}\ k, d \in M, p \in P, a, e \in F$



Identified optimal vertiport locations and user allocation

Policy Questions on Landside Infrastructure of AAM



Airport landside

- Airport authority
- Local transportation agency

Advanced Aerial Mobility

1. Urban and regional air mobility
2. Cargo logistics
3. Others

Micromobility

- City
- Transit authority

Photo Source: https://www.nasa.gov/sites/default/files/thumbnails/image/uam-3-4x3-v2-sm.jpg

Policy Questions on Landside Infrastructure of AAM

- Public owned or private owned?
- Exclusive, Preferential, or Shared?
- Integrate with local transit, park n ride?

Advanced Aerial Mobility

1. Urban and regional air mobility
   - City
   - County
   - County transit authority
   - Regional transit authority
   - State

2. Cargo delivery
   - Besides, local community

3. Emergency medical services, first responders, disaster relief

Photo Source: https://www.nasa.gov/sites/default/files/thumbnails/image/uam-3-4x3-v2-sm.jpg

Policy Questions on Market Entrance of AAM

CITY COUNCIL APPROVES REGULATIONS FOR SHARED MOBILITY

This week, the Council voted to pass an ordinance to establish licensing and regulations for shared mobility businesses, such as electric scooters.

March 29, 2019

PUBLISHED BY:
CITY COUNCIL

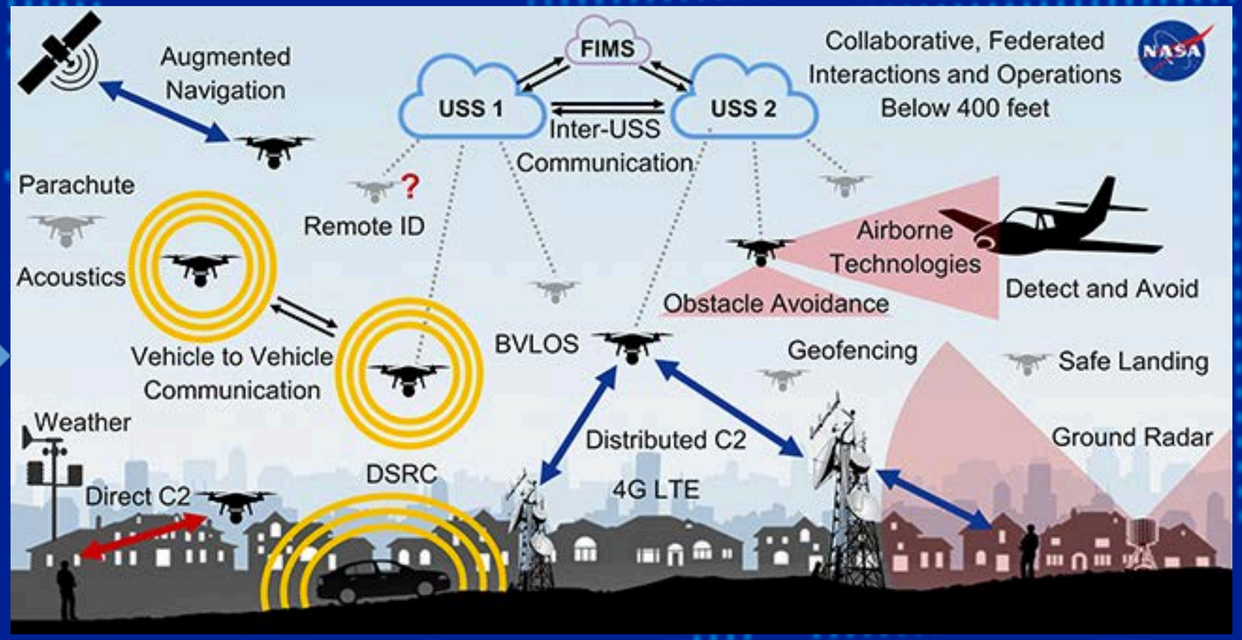
Local regulation and license structure on advanced aerial mobility?
What should be considered?

Photo Source: https://www.nasa.gov/sites/default/files/thumbnails/image/uam-3-4x3-v2-sm.jpg

ATM and UTM

This instrument flight rules chart shows low altitude airways in the Oakland Area Control Center (near San Francisco, California).

Advanced Aerial Mobility



Unmanned Aircraft System (UAS) Traffic Management (UTM)
Enabling Civilian Low-altitude Airspace and Unmanned Aircraft System Operations
Source: https://utm.arc.nasa.gov/index.shtml

Concept of Automated Traffic Management of AAM

Safety

- Obstacles avoidance
- Trajectory deconfliction

Efficiency

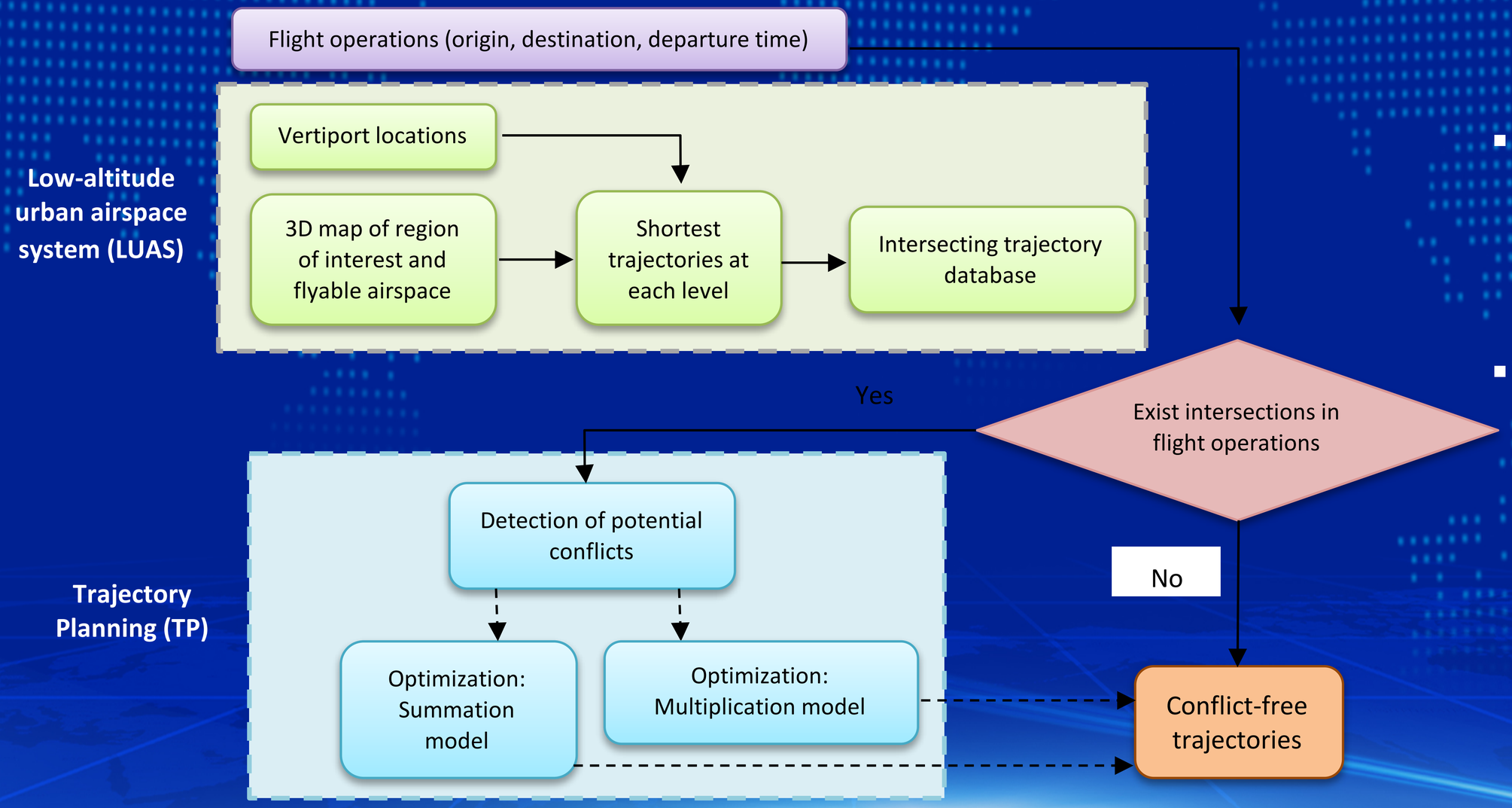
- Energy consumption

Equity

- Nash social welfare

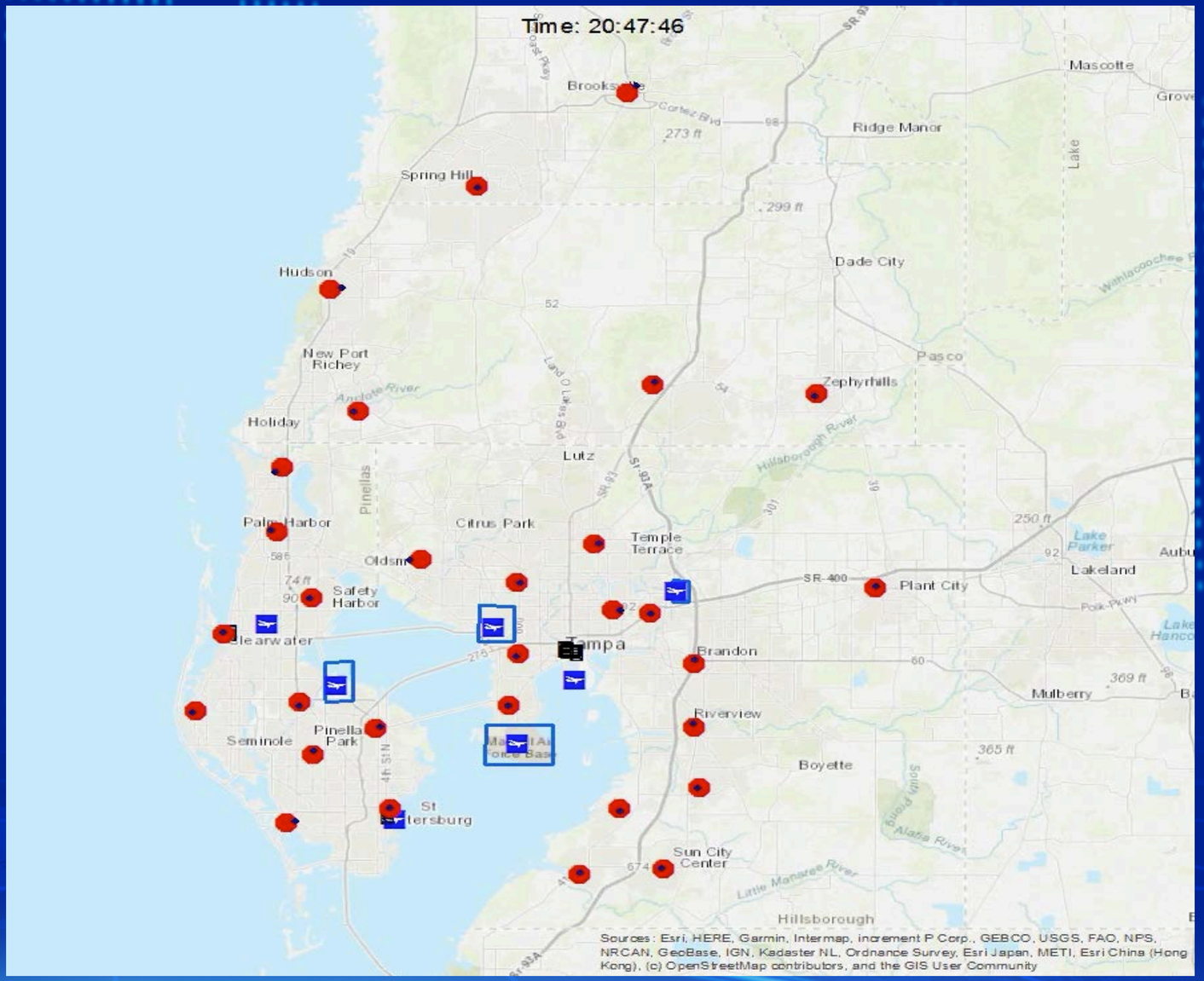
- Centralized service center
- Airspace design
- Management schemes
- Trajectories planning
  - Conflict detection and resolution
  - System efficiency

Airspace Design and Trajectory Planning for AAM



- **Low-altitude airspace system:** generate flyable airspace and flight routes.
- **Trajectory planning:** conflict-free, energy-efficient, and equitable operations.

Case Study - Trajectory Planning for Tampa Bay Area AAM Operations



Policy Questions on Airspace Design of AAM

National roadway system with hierarchy and different imposed speeds

?

Advanced Aerial Mobility

- Size
- Speed
- Cargo or passenger
- Emergency exemption
- Others

Policy Questions on Airspace Structure of AAM

Air Route Traffic Control Center

Advanced Aerial Mobility Region? End-to-end coverage?

THANK YOU

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