Canonical Use Cases for Critical Infrastructure

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70RSAT20FR0000062, Next Gen Resilient Position, Navigation, and Timing (PNT), to develop and maintain the Nation's technical expertise, frameworks and artifacts necessary to guide users, product integrators and supply chain manufacturers on government expectations related to PNT system resilience.

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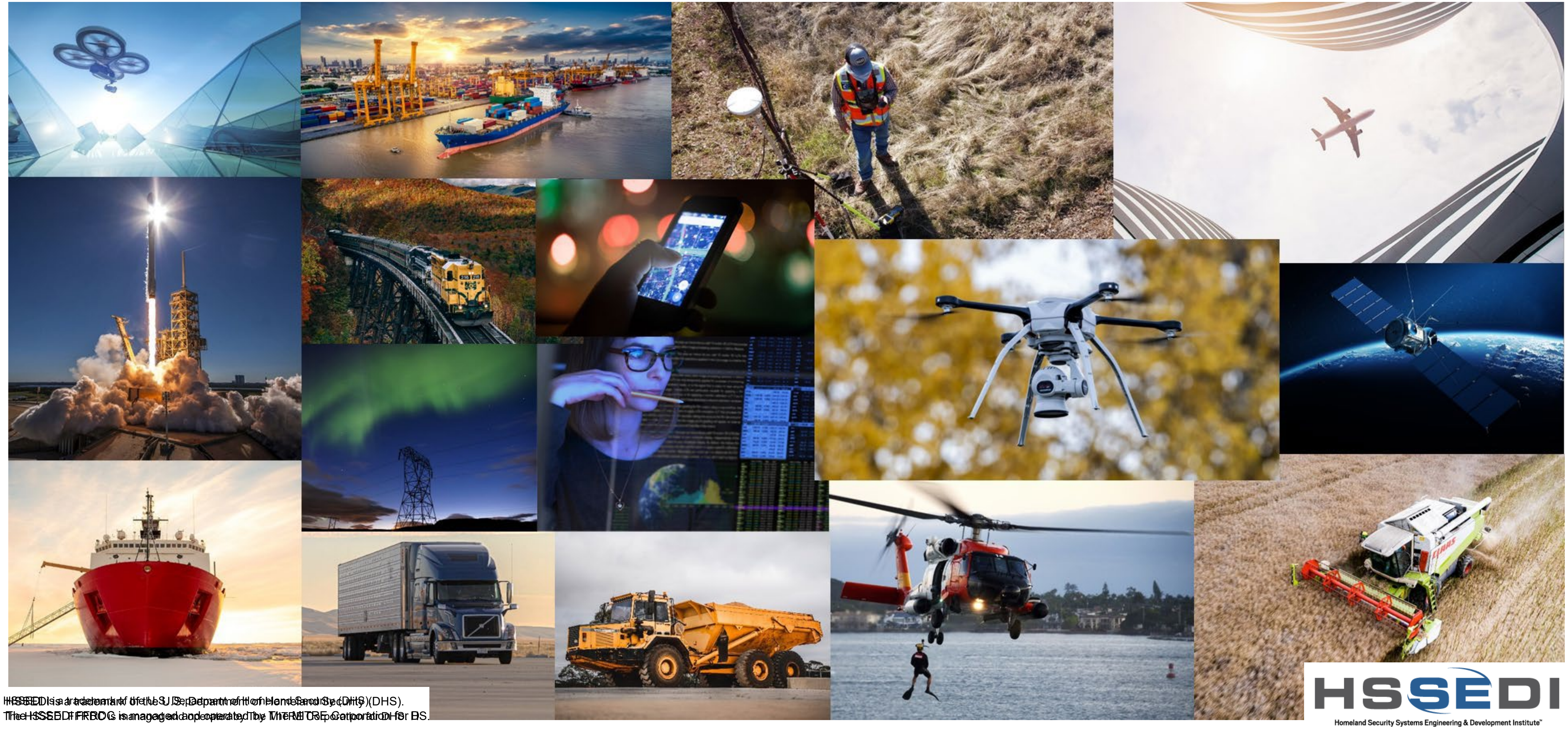
Introduction

- **Satellite navigation and timing (satnav), especially GPS, is used for positioning, navigation, and timing (PNT) in many different critical infrastructure applications**
  - "Critical Infrastructure are those assets, systems, and networks that provide functions necessary for our way of life."†
- **There are many ongoing efforts to develop and field alternative PNT technologies that complement, augment, back up, or replace satnav in critical infrastructure applications**
- **These slides describe a set of use cases that "span the space†" of critical infrastructure applications, allowing structured examination of the extent that alternative PNT technologies satisfy critical infrastructure needs**

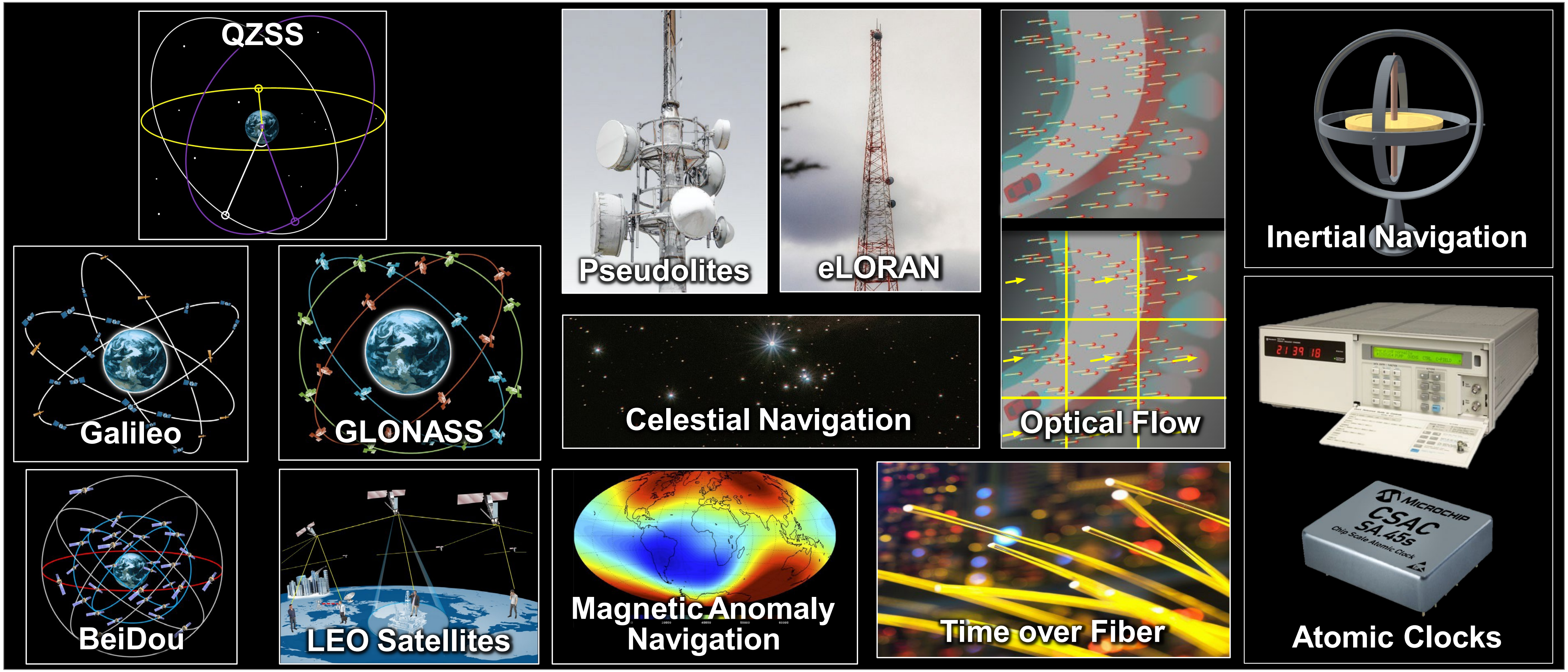
  †Describe the range of needs with minimal duplication
- **Certified aviation not included, since FAA is addressing that separately**

†Critical Infrastructure Security and Resilience | Cybersecurity and Infrastructure Security Agency CISA

Currently, GPS Currently Is Widely Used to Meet PNT Needs



Many Alternative PNT Technologies Are Being Pursued



Scenario Specific Evaluation Criteria

1. **Functions**
   - Positioning
   - Navigation
   - Timing
2. **Measurement accuracy**
   - When a use case has varying measurement accuracy needs, the most stringent is reported
3. **Service region**
   - Portions of United States
   - Entire United States (50 states and territories)
   - Worldwide
   - Worldwide and space
4. **Operating conditions**
   - Underwater/underground
   - Deep indoors
   - Earth surface vs. airborne vs. space
   - Day vs. night
   - Weather
5. **Acceptable user device cost, size, weight, and power (CSWaP)**
   - High CSWaP: Expensive and rack mounted
   - Modest CSWaP: Modest cost and fits in a shoebox
   - Low CSWaP: Compatible with a consumer device

Proposed Use Cases (1 of 3)

Use Case	PNT Func.(s)	Meas. Accuracy	Service Region	Operating Conditions	CSWaP	Ref.
Cellular Base Station: Intercell Interference	T	± 1 μs	Entire U.S.	All Earth Surf.	Mod.	1
Cellular Base Station: Carrier Aggregation	T	± 0.13 μs	Entire U.S.	All Earth Surf.	Mod.	2
Phasor Measurement Unit	T	± 1 μs	Entire U.S.	All Earth Surf.	Mod.	3
Financial Trading	T	± 50 ms (US), ± 1 μs (EU)	Urban Areas	All Earth Surf.	High	3, 12
Positive Train Control	P	2D 1 m (2DRMS)	Entire U.S.	All Earth Surf.	High	3
Precision Agriculture, Other Commercial	P, N	±1 cm H, ±1.5 cm V	Entire U.S.	All Earth Surf.	Mod.	–

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Proposed Use Cases (2 of 3)

Use Case	PNT Func.(s)	Meas. Accuracy	Service Region	Operating Conditions	CSWaP	Ref.
Driving: Route Navigation	P, N	2D 3 m (2DRMS)	Entire U.S.	All Earth Surf.	Low	–
Driving: Lane Navigation	P, N	2D 1 m (2DRMS)	Entire U.S.	All Earth Surf.	Low	3
Driving: Autonomous Vehicles	P, N	2D 0.1 m (2DRMS)	Entire U.S.	All Earth Surf.	Mod.	–
Space Launch	P, V	3D 5 m RMS, 0.1 m/s per axis	World-wide to GEO	All	Mod.	7, 8, 9
Space Operations	P	3D 1 m (95%) at LEO	LEO to GEO	Space	Mod.	10

Proposed Use Cases (3 of 3)

Use Case	PNT Func.(s)	Meas. Accuracy	Service Region	Operating Conditions	CSWaP	Ref.
Maritime: Ocean/ Seas	P, N	2D 185 m (2DRMS)	Worldwide	All Earth Surf.	High – Mod.	3
Maritime: Harbors	P, N	2D 8 m (2DRMS)	Entire U.S.	All Earth Surf.	High – Mod.	3
Maritime: Inland Waterways	P, N	2D 2 m (2DRMS)	Entire U.S.	All Earth Surf.	Mod.	3
UAS En Route	N	2D 1 m (2DRMS)	Entire U.S.	Airborne	Mod.	3
UAS Sensing	P	± 1 cm H, ± 1.5 cm V	Entire U.S.	Airborne	Low	4, 5, 6
Emergency 911	P	2D 50 m (for 40% of wireless calls)	Entire U.S.	All Earth Surf.	Low	11

Other Considerations

- **All technologies must be adequately robust against threats to the technology, infrastructure, and user device**
  - Need red teaming to identify, assess, and mitigate technology-specific vulnerabilities
  - Can't focus only on GPS-specific vulnerabilities—how will new technologies be attacked?
    - User devices
    - Infrastructure that provides PNT information to user devices
- **Time frame when PNT infrastructure and user devices can be operational must be considered**
- **Costs to develop, acquire, install, sustain any PNT infrastructure must be considered**
  - Commercial fee for service vs. government-provided

Observations

- **Different use cases provide different sets of characteristics to be met**
  - Underground, underwater, deep indoors not yet addressed
- **All the timing use cases involve stationary user devices**
  - More good technology options for timing applications than positioning applications
- **Compare positioning use cases to recent evaluation of GNSS backups by Joint Research Center of European Commission†**
  - Positioning error < 100 m 95%
  - Service region limited to EU European territory
  - No explicit consideration of user device CSWaP
- **Combinations of technologies can be explored**
  - Diversity increases resilience, but robustness is needed and increased CSWaP must be considered
- **Additional PNT infrastructure is useless unless corresponding user devices are developed, acquired, integrated, installed, sustained**
  - Will critical infrastructure owner/operators make the investment?

† Backing Up GNSS - Inside GNSS - Global Navigation Satellite Systems Engineering, Policy, and Design

Example Scorecard

Use Case	Criteria Satisfied	Criteria Not Satisfied
Cellular Base Station: Intercell Interference		
Cellular Base Station: Carrier Aggregation		
Phasor Measurement Unit		
Financial Trading		
Positive Train Control		
Precision Agriculture, Other Commercial		
Driving: Route Navigation		
Driving: Lane Navigation		
Driving: Autonomous Vehicles		
Space Launch		
Space Operations		
Maritime: Ocean/ Seas		
Maritime: Harbors		
Maritime: Inland Waterways		
UAS En Route		
UAS Sensing		
Emergency 911		

Potential Way Ahead

- **Seeking feedback**
  - Use cases to add, modify, or delete?
  - Criteria to add, modify, or delete?
- **Apply resulting use cases for proposed PNT technologies**
  - Obtain/assume performance standards for PNT technologies and user devices
  - Evaluate utility of individual PNT technologies
  - As needed, consider sets of technologies to meet needs of all use cases
  - Evaluate other considerations: robustness, time frame for operational capability, costs of PNT infrastructure, adoption potential

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