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Assuring Space Mission Success

Project SEXTANT
New Thinking on Alternative PNT

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Project **SEXTANT**

An internal **Aerospace** study on new thinking in **Alternative PNT**

Alternative PNT: Precision Positioning, Navigation, and Timing in the absence of GPS as the primary PNT source.

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Explore Alternative PNT

- ▷ Identify and examine options
- ▷ Identify the **key factors** needed to **catalyze** development
- ▷ Develop a ‘way forward’ strategy

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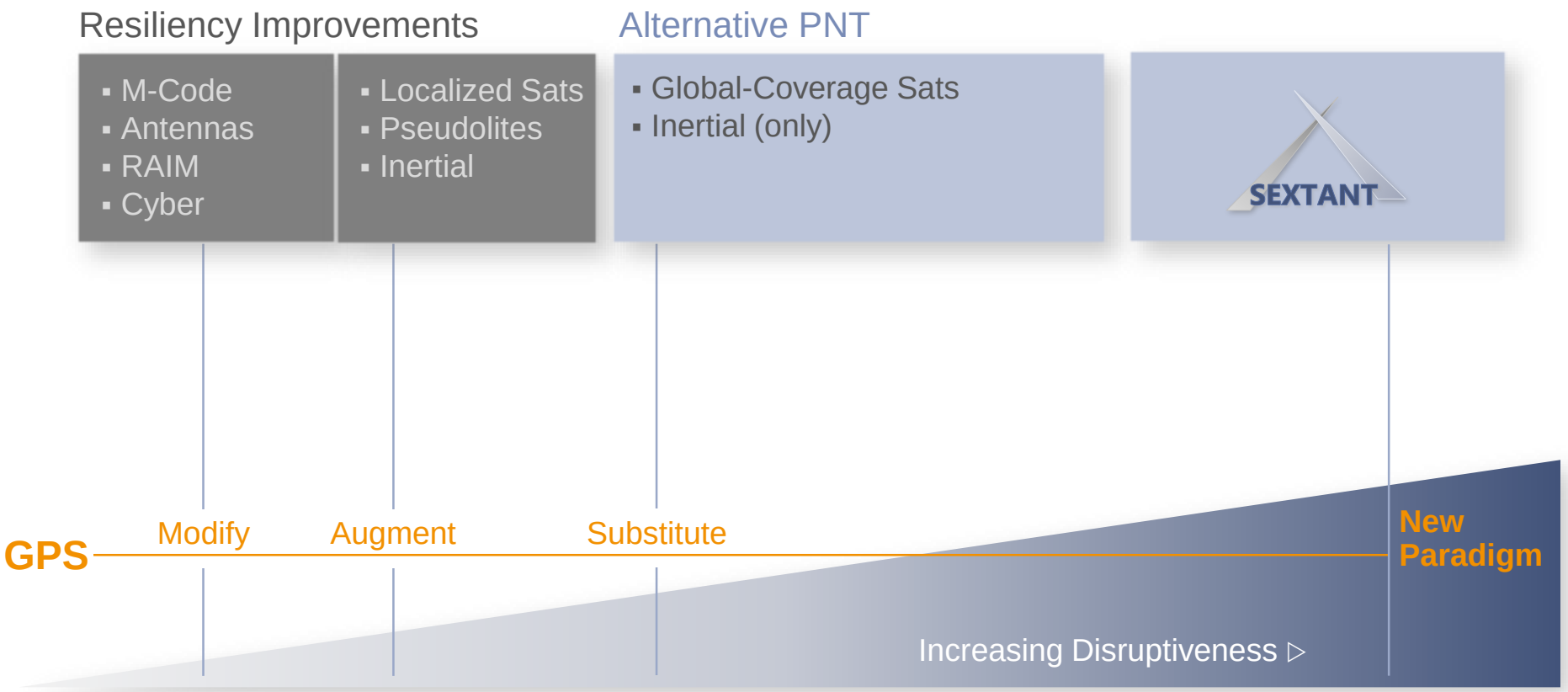
PNT Innovation Landscape



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Summary of Major Findings and Outcomes

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Major Findings

- GPS is **vertically integrated**
- No obvious **'Drop-In'** replacement
- Novel **combinations** of multiple approaches is fertile ground for **PNT innovation**
- An **independent** body is needed to **evaluate** and **coordinate Alternative PNT** concepts for critical functions

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- Many experts have been working on GPS alternatives for some time with no clear consensus crystallizing on a path forward

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GPS as a PNT Source

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The Birth of GPS

[redacted]

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(U) Briefing– Navigation Satellite Study

24 AUGUST 1966

Prepared by J. B. WOODFORD and H. NAKAMURA
System Planning Division

Prepared for COMMANDER SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California

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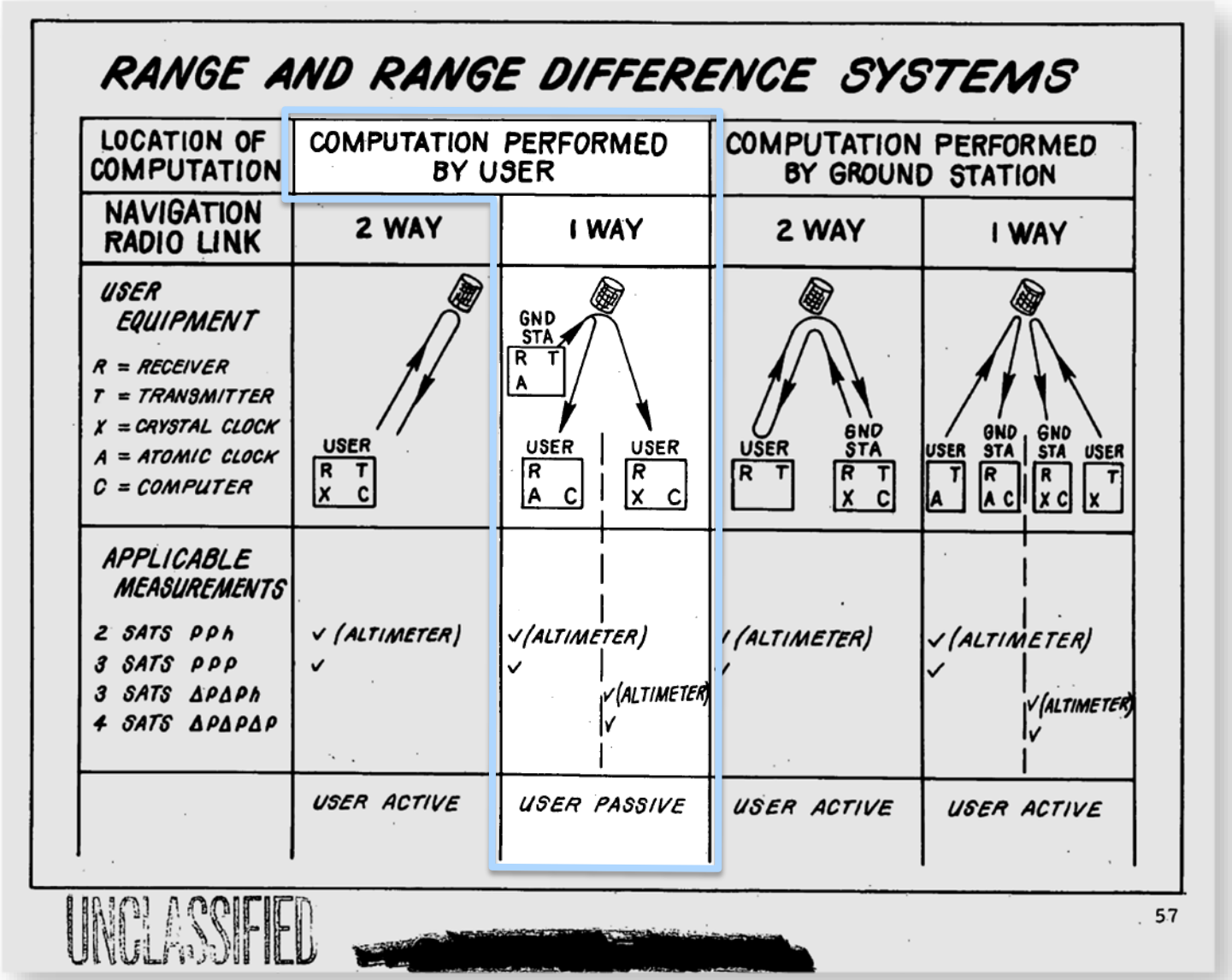
Radionavigation from Space



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Influence of Prevailing Technology on GPS

1966

- Simpler RF environment
- Focused mission applications
- Electronic components were large
- Processing power at its infancy
- Government at the forefront of technological innovation

2015

- Rich ambient RF ‘flora and fauna’
- Plethora of users
- Electronic component size is no longer an issue
- Intensive processing in portable devices is a reality
- Technology permeates all sectors with many sources of innovation

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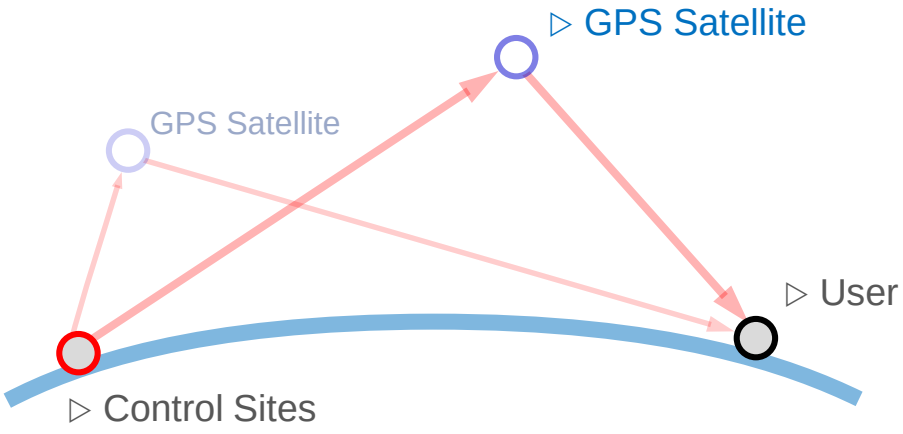
GPS Functional Decomposition

Position & Time

	Position	Time
Processor	Position **TOA**	Time **Kalman Filter**
Receiver	Position **User (RF)**	Time **User (RF)**
Transmitter	Position **Satellites (RF)**	Time **Satellites (RF)**
PNT Data	Position **Sat. Position**	Time **UTC**
Reference	Position **Orbital Motion**	Time **Atomic Clock**
Phenomenon	Position **Radionav.**	Time **Cesium Atom**



GPS

- ▷ Vertically integrated
- ▷ Satellites act as a **relay** of **PNT data** (orbital position)

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Basis for an Alternative-PNT Framework

GPS

Position & Time

	Position	Time
Processor	TOA	Kalman Filter
Receiver	User (RF)	User (RF)
Transmitter	Satellites (RF)	Satellites (RF)
PNT Data	Sat. Position	UTC
Reference	Orbital Motion	Atomic Clock
Phenomenon	Radionav.	Cesium Atom

PNT Components
Contribute to a PNT solution but cannot otherwise generate a solution alone

PNT Concept
A complete system capable of producing a PNT solution

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Many PNT Components Identified

Position & Time

	PNT Components Identified
Processor	23
Receiver	18
Transmitter	12
PNT Data	23
Reference	16
Phenomenon	15

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- Over 100 PNT components identified and put into context
- Decomposing GPS into **PNT Components** gives us a new way to develop and describe alternatives

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Innovating Alternative PNT
Inspiration from Other Sectors

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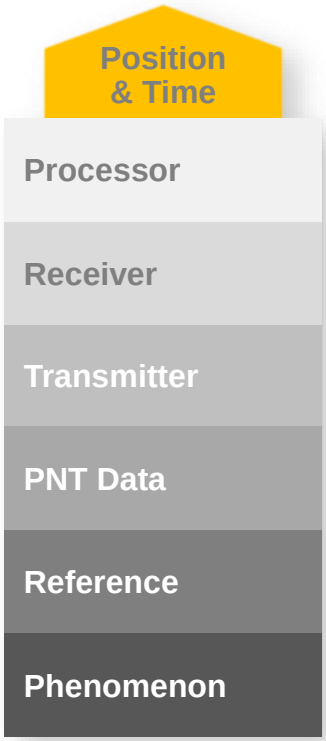
Vertical to Horizontal Integration in PNT



GPS
(Vertical Integration)

Address Alternative PNT from the standpoint of **transitioning** from a **vertical** to a **horizontal** architecture

Vertical = tightly controlled
Horizontal = flexible

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What We Can Learn From Other Sectors

There are several sectors that have relevant experience in vertical/horizontal transition

- **Telecom**
  - Ma Bell transitioned to cell phones

- **Media**
  - Early emphasis on controlling distribution (infrastructure) transitioned to content

napster. ▸ iTunes ▸ PANDORA

- **Technology**
  - Tightly controlled desktop ecosystem transitioned to cloud computing

Windows 95 ▸ ▸ amazon webservices

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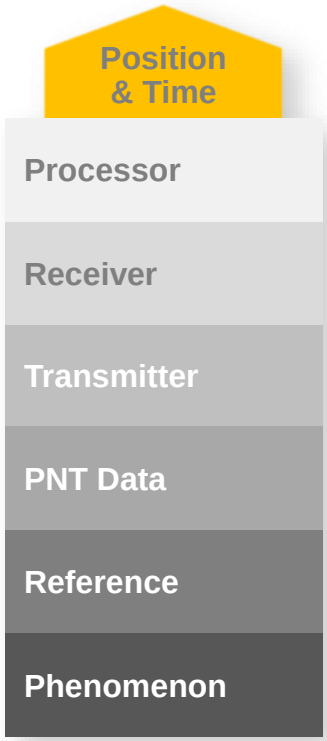
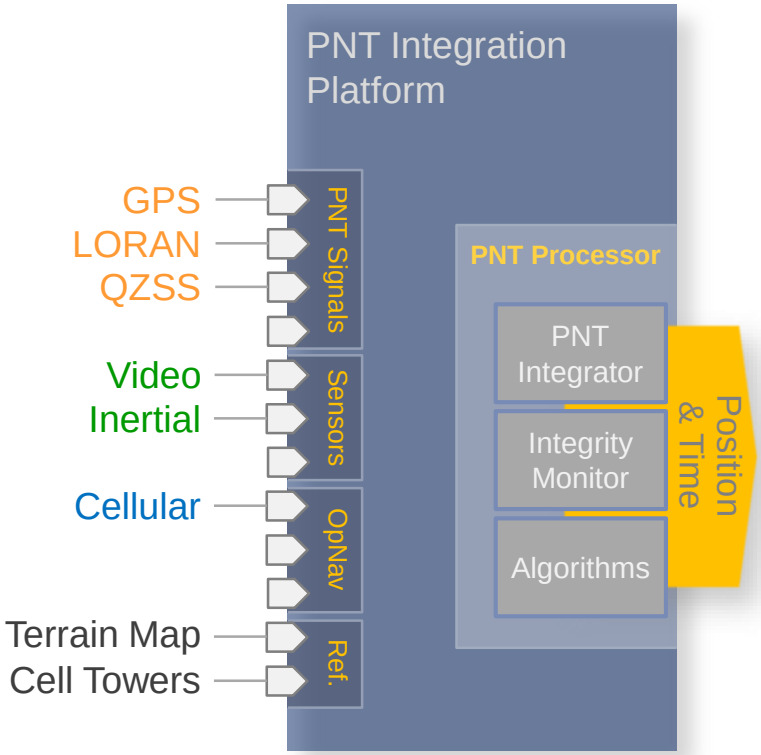
Creating a PNT Ecosystem



GPS
(Vertical Integration)



Open-Source Alternative PNT
(Horizontal Integration)

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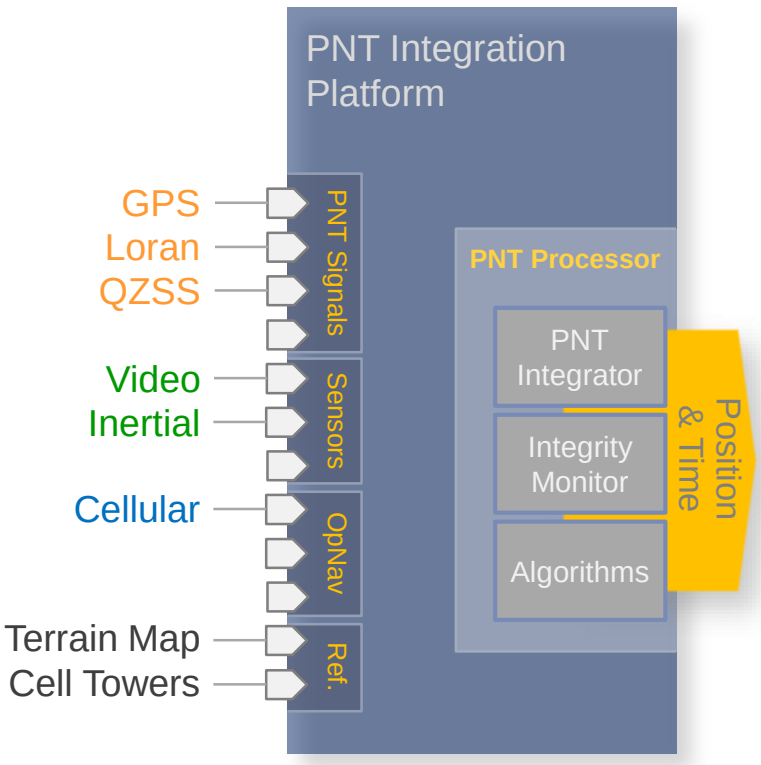
Open Source PNT



Alternative PNT Ecosystem

- Flexible **horizontal** architecture
- Creates a **modular ecosystem** for developing PNT components
- **Dynamically** integrates **multiple types** of PNT components
- Separates **platform** stewardship from **application** development
- **Distributes PNT** over many devices, technologies, and phenomenology

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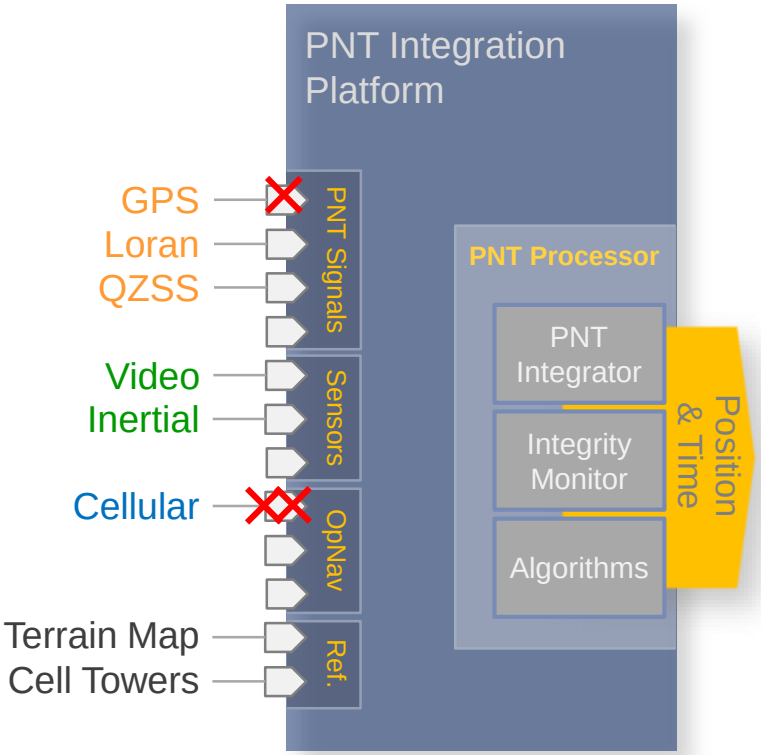
Resiliency Through Flexibility



× = degraded quality

⨯ = tampering suspected

Flexible Architecture serves as a '**nudge**' to **change behavior**

- End users take on greater responsibility for PNT integrity
- Increased awareness with a "**PNT Quality**" indicator

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Alternative PNT Framework

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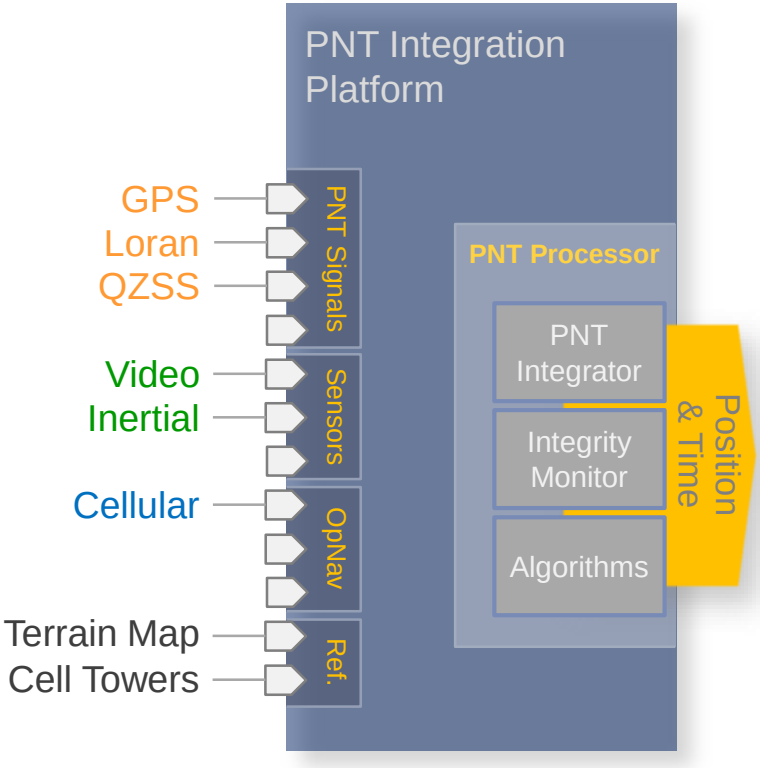
Evaluating PNT Concepts



Which Combination of PNT Inputs To Choose?

- A framework for assessing user satisfaction is critical to support decision making

Open-Source Alternative PNT

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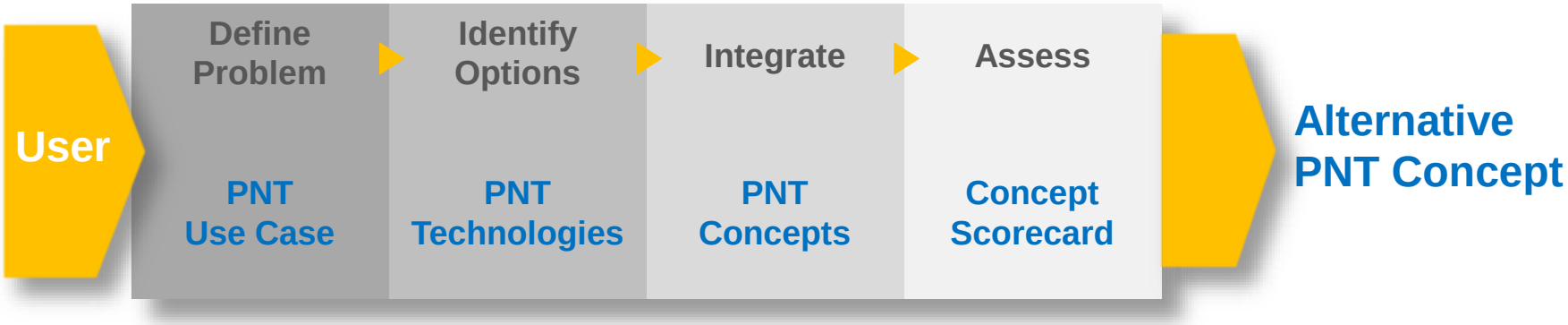
Alternative PNT Assessment Workflow



The **Alternative PNT Framework** is the basis for an evaluation process:

- Identify and Evaluate **PNT Component Technologies**
- Develop and Integrate **Concepts**
- **Assess User Satisfaction**

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An internal **Aerospace** study on new thinking in **Alternative PNT**

The **Alternative PNT Framework** opens the aperture on future thinking

- The **Open-Source PNT Concept** illustrates the value of considering **different business models**
- The **Framework** highlights opportunities that may emerge from **disaggregating** the PNT **user base**
- Examining **critical PNT functions** across the **DOD**, **civilian**, and **commercial** sectors is worthy of investment to quantify **user needs** and **options for satisfying them**

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