33rd Annual INCOSE international symposium

hybrid event

Honolulu HI USA

A Less-than-Truckload (LTL) Problem

A Systems Engineering Approach to Reducing Mis-pulls and Misplaced Trailers for Trucking Fleets

Trae Span, Dr. Jeremy Daily, and Sean Bumgarner

About the Authors and Overview

Trae Span

Martin "Trae" Span is currently a PhD Student in Systems Engineering at Colorado State University

- Major in the United States Air Force (USAF).
- Served the USAF as a Developmental Test Engineer.
- Served as Deputy Director for the US Air Force Academy systems engineering program.
- His PhD work is focused on cybersecurity requirements elicitation for complex cyber-physical systems.

Dr. Jeremy Daily

Jeremy Daily. Dr. Daily teaches systems engineering at Colorado State University in Fort Collins, CO.

- His research interests include:
  - vehicle cybersecurity
  - digital forensics
  - crash reconstruction.
- He helped start the CyberTruck Challenge in 2017 where academia, government, industry, and security researchers come together to understand and improve the cybersecurity posture of heavy vehicle systems.
- Dr. Daily received his Ph.D. in engineering from Wright State University in Dayton, OH after a tour of duty in the US Air Force.

Sean Bumgarner

Sean Bumgarner. Sean is a Master's student at Colorado State University.

Sean's research interests include:

- Adapting Systems Engineering for the trucking industry
- Driver behavior
- Heavy vehicles communication systems Integrations with TSPs
- Heavy vehicle cyber security,
- Establishing recommended practices for the industry.

Sean has mathematics degree from Saint John's University in Collegeville, MN and an industrial engineering degree from North Dakota State University in Fargo, ND.

Where Form Meets Function

Cyber Truck Challenge

- Students Gain Hands-on Experience
- Knowledgeable Professionals with Practical Knowledge
- Having Great Sponsors that Allow Exploration
- cybertruckchallenge.org

https://www.cybertruckchallenge.org/past-challenges/2021-2/

Presentation Overview

- Introduction
- Mission Analysis—Background on Trucks and Trailing Equipment
- Stakeholder Needs Analysis
- System Requirements
- Trade-off Analysis
- Operational Feasibility Analysis
- System Implementation on a Prototype
- Verification and Validation
- Recommendations and Conclusions

Studying Mis-Pull and Location

https://www.freightwaves.com/news/freightliner-supertruck-ii-looks-for-technology-life-after-research

Introduction

Less-than-Truckload (LTL) Trucking Mis-pull and Trailer Location

Problem Overview

- Trucking companies, especially less-than-truckload (LTL) trucking companies switch trailers often
- Trailer to tractor ratio = 3:1
- Connect → Pull → Disconnect
- Selection of the wrong trailer is called a mis-pull
- Every mile of a mis-pull is unproductive, costly and wasteful

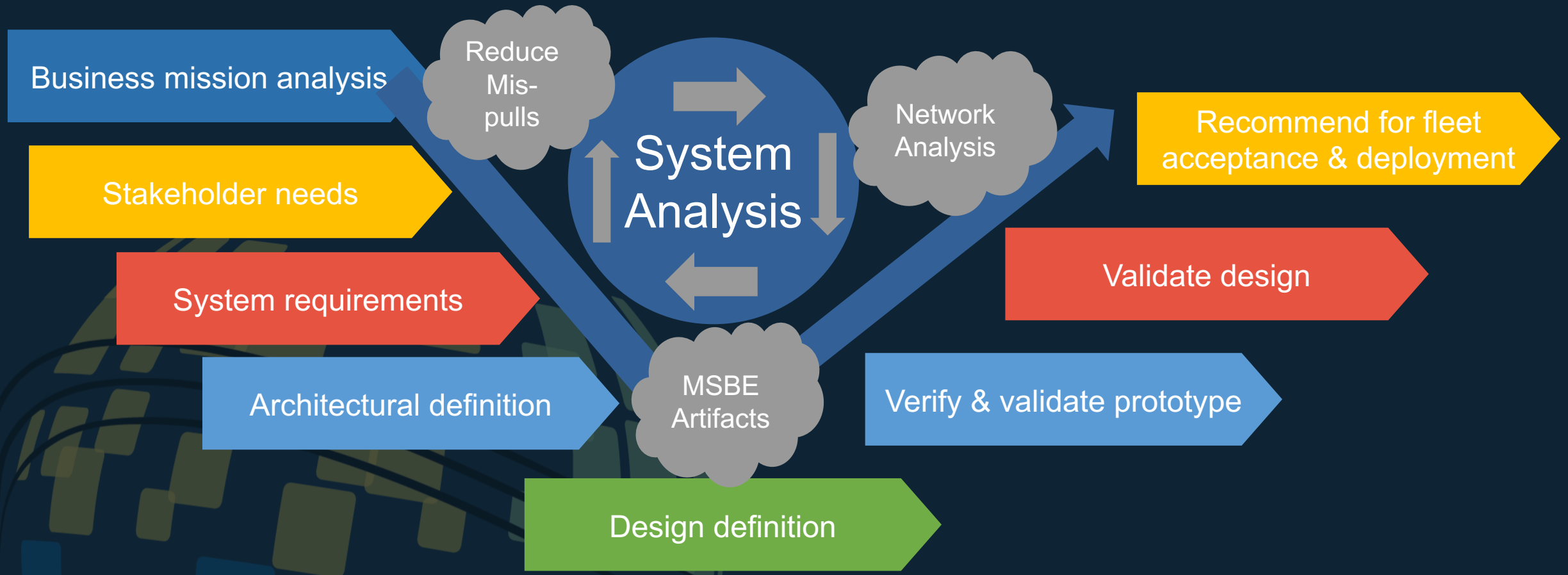
https://www.youtube.com/watch?v=jE1C6PJbmeI

Previously Attempted Solutions for Trailer Identification

- Radio Frequency Identification Systems
  - Read Rates are too low
- Stand Alone Trailer Locator
  - Short Battery Life
  - Solar mounts are unreliable

https://www.rfidinc.com/applications/vehicle-identification/

Project V-Diagram

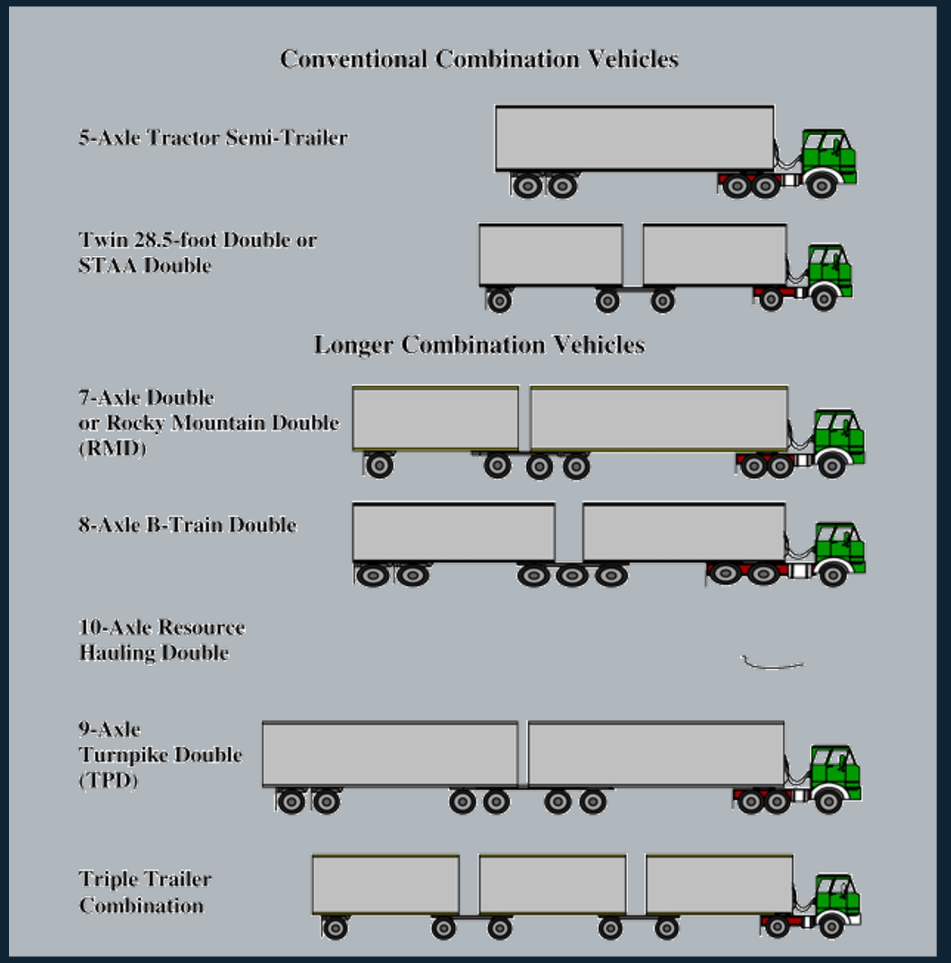


Mission Analysis

Trucks and Trailing Equipment

Less-Than-Truckload (LTL) Tractor-trailer Combinations

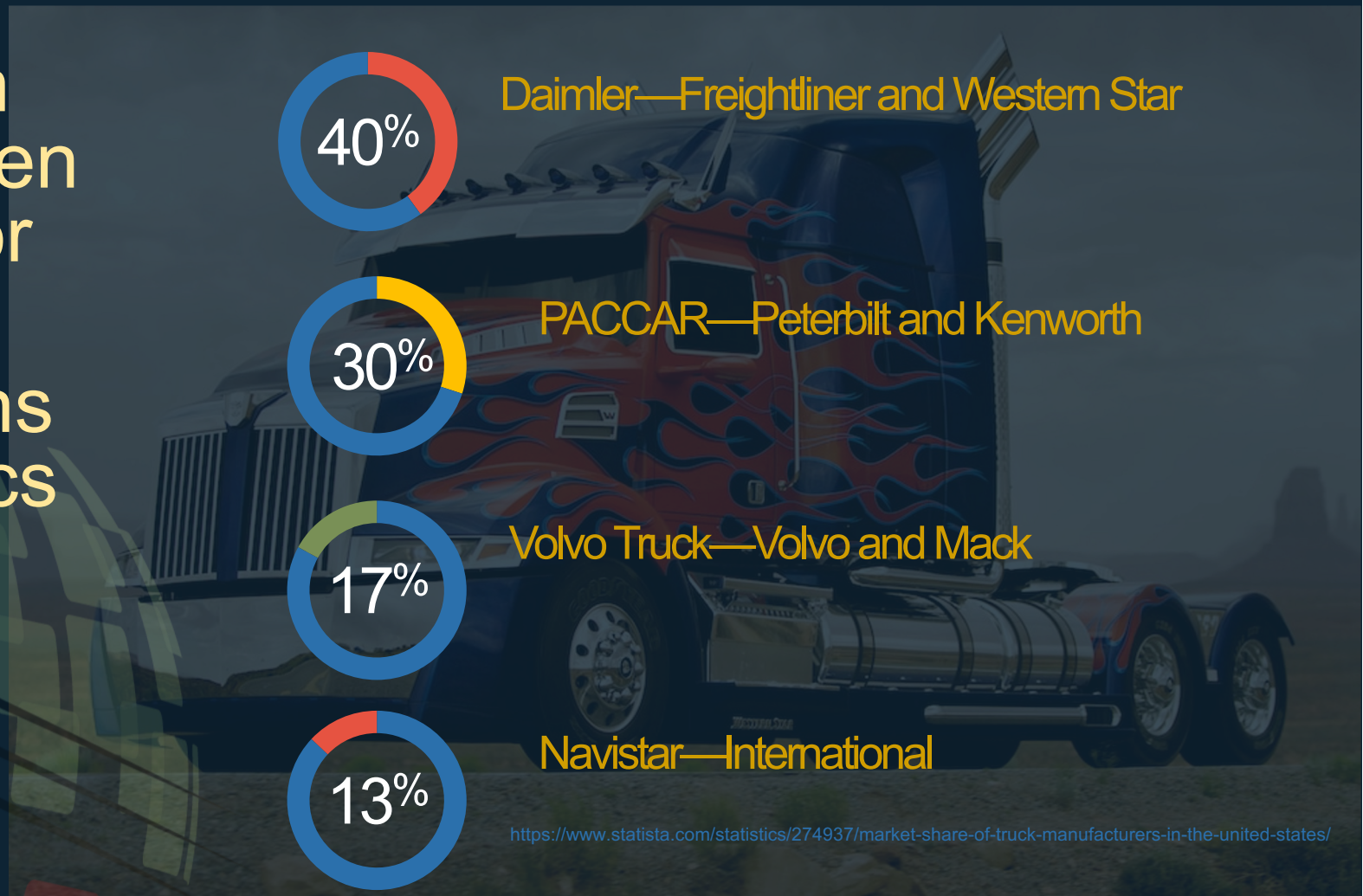
- Allows multiple destinations in one dispatch
- Minimizes handling
- Increases capacity
- Increases complication with additional trailers



https://www.fhwa.dot.gov/policy/otps/truck/wusr/chap02.cfm

Original Equipment Manufacturers (OEMs)

- The most common relationship between trucking and tractor OEMs
- The tractor contains the most electronics
- The tractor is the most expensive rolling asset for an LTL fleet



https://www.statista.com/statistics/274937/market-share-of-truck-manufacturers-in-the-united-states/

https://www.motortrend.com/news/163-1403-western-star-brings-optimus-prime-to-mid-america-show?galleryimageid=2f86dd6d-d543-464f-8f22-624810275912&test=control

Architecture Inside Truck and Trailer

Trailing Equipment Configuration

Single Tractor-
Semi Trailer

"Western" Double

Triple Trailer
Combination

https://www.flickr.com/photos/granitefan713/17198965979

Technology Timeline

PLC4TRUCKS

1986

Standard

https://www.sae.org/publications/technical-papers/content/861069/

Regulation

1997-8

Anti-Lock Brakes Required on Trailers

Cell Phone Location Tracking

2004

Standard

Regulation

2019

Electronic Logging Devices Required

Smarter Trailers

2023

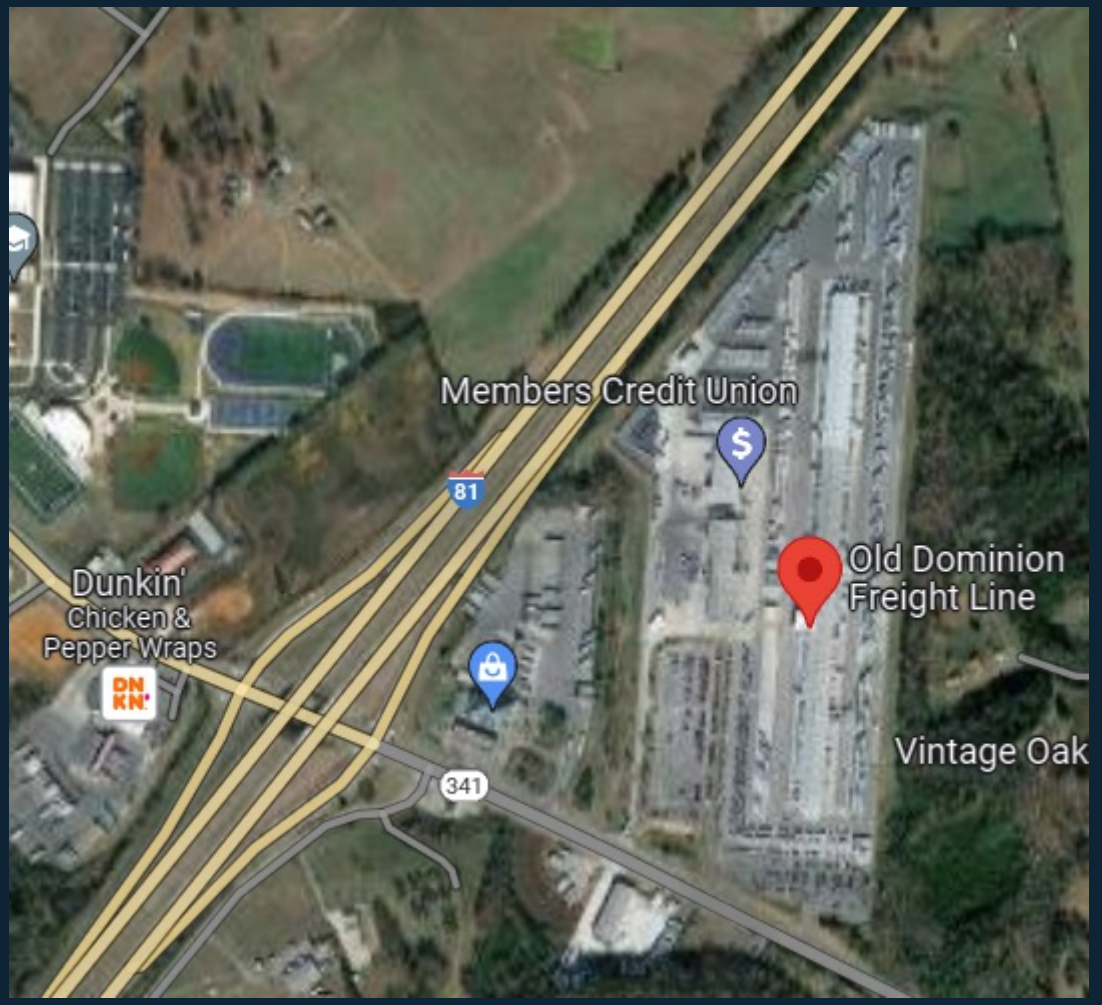
Standard TBD

Mission Analysis

Stakeholder Needs Analysis

Size and Scope

- Less-than-truckload (LTL) market segment grew 4.3 percent in 2022
- LTL in US has $103 billion dollars operational expenditures annually
- The LTL market has three million tractors and greater than nine million trailers



https://www.google.com/maps/place/Old+Dominion+Freight+Line/@36.109357,-83.3398364,2086m/data=!3m1!1e3!4m6!3m5!1s0x885b949cf897c205:0xf09ce7eb0cdc7993!8m2!3d36.1098794!4d-83.3299061!16s%2Fg%2F1tf3pmfy?entry=ttu

Fleet Needs Analysis

The primary stakeholders are the less-than-truckload (LTL) carriers, and they need to:

- Implement trailer tracking technology cost-effectively across fleet
- Decrease the probability of mis-pulls (pulling the wrong trailer) during operations
- Improve freight security
- Improve operational processes of:
  - Identification
  - Location
  - Rescue
- Better trailer utilization

https://www.google.com/search?sxsrf=AB5stBgPXrRGi1W7m8KBzI8mLBCaQj5X0A:1689792612437&q=fedex+freight+memphis+tn&npsic=0&rflfq=1&rldoc=1&rllag=35060354,-90025714,2234&tbm=lcl&sxsrf=AB5stBgPXrRGi1W7m8KBzI8mLBCaQj5X0A:1689792612437&sa=X&ved=2ahUKEwjj4aGDuJuAAxWkKn0KHVkSBNgQtgN6BAgUEAE&biw=1536&bih=722&dpr=1.25#lpg=cid:CgIgAQ%3D%3D,ik:CAoSLEFGMVFpcFBKSXJsY09OZmhHNDBtSndqWlJzcGltV2NFSXlXZmRfa2RNRVRO

System Over-arching Objectives

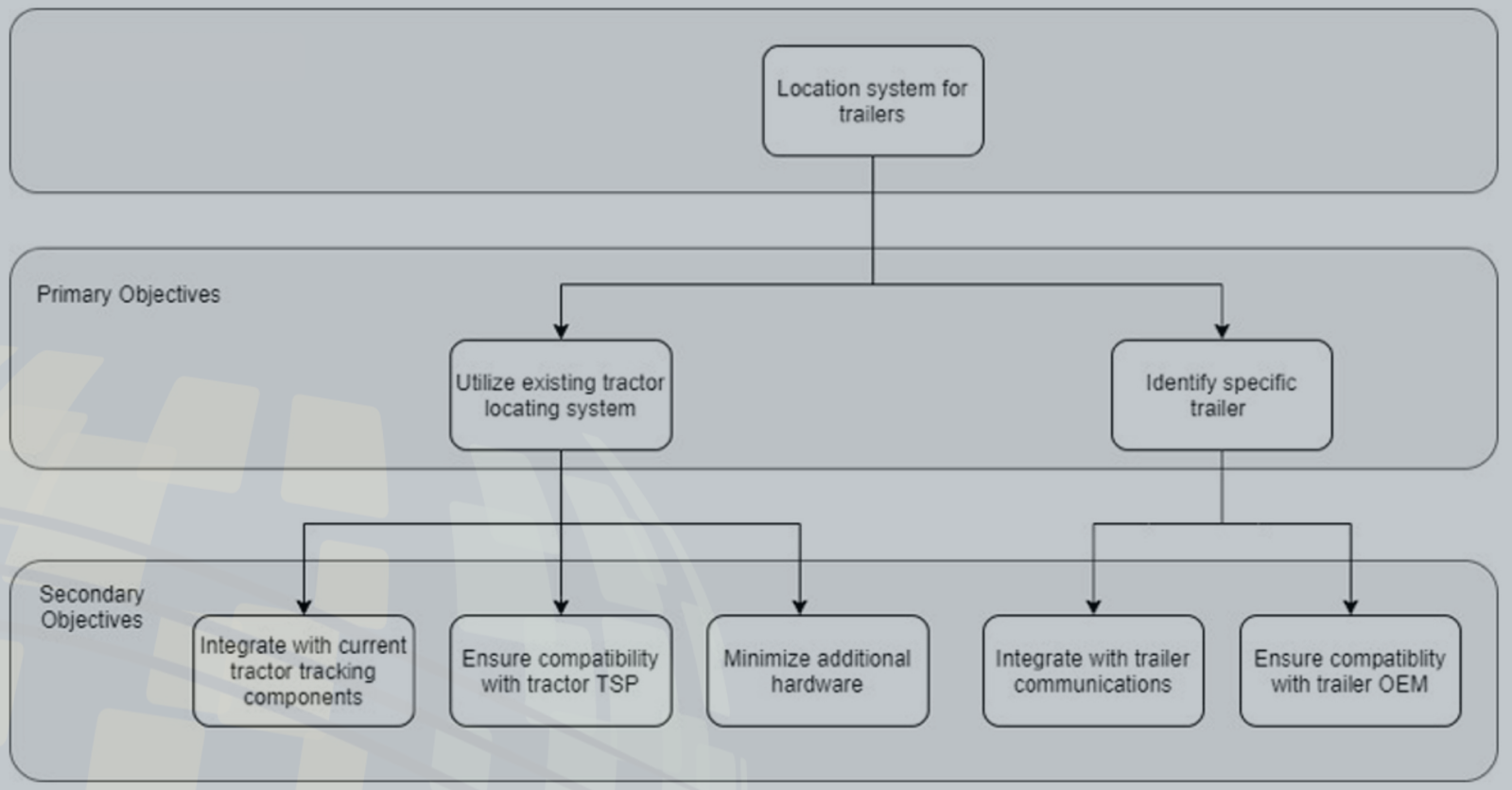


Figure 3: Hierarchy of system objectives as articulated by the customer, an LTL freight company.

Functional Flow Block Diagram

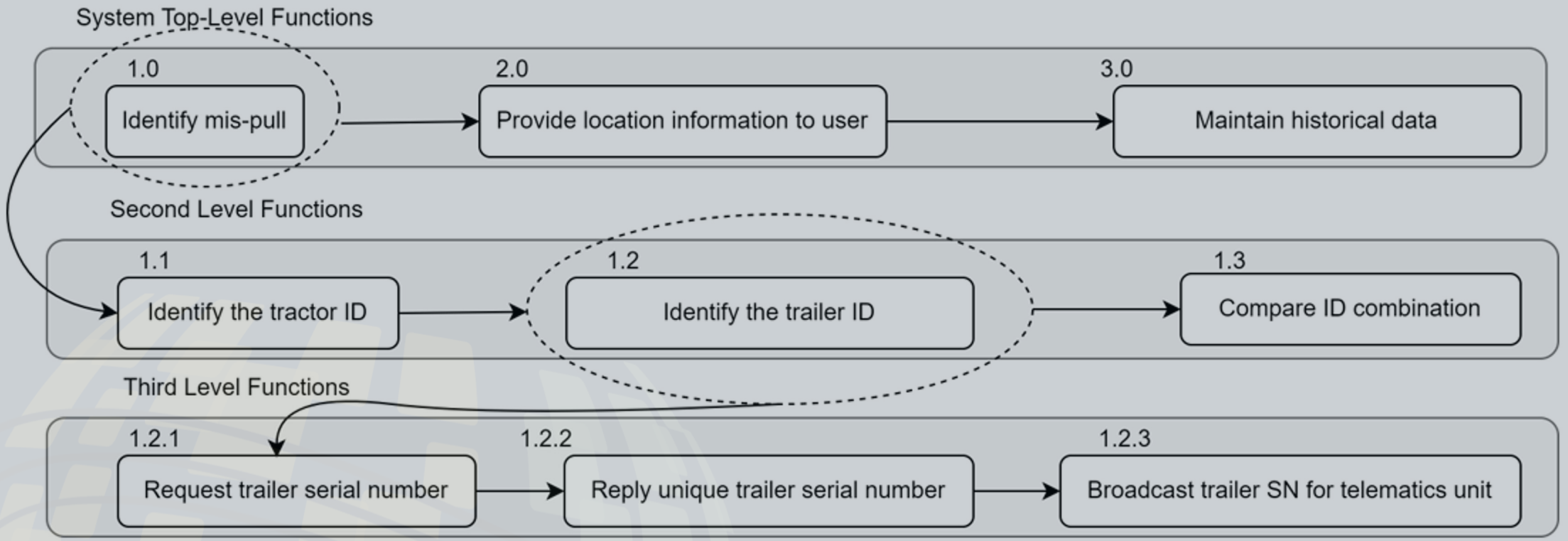
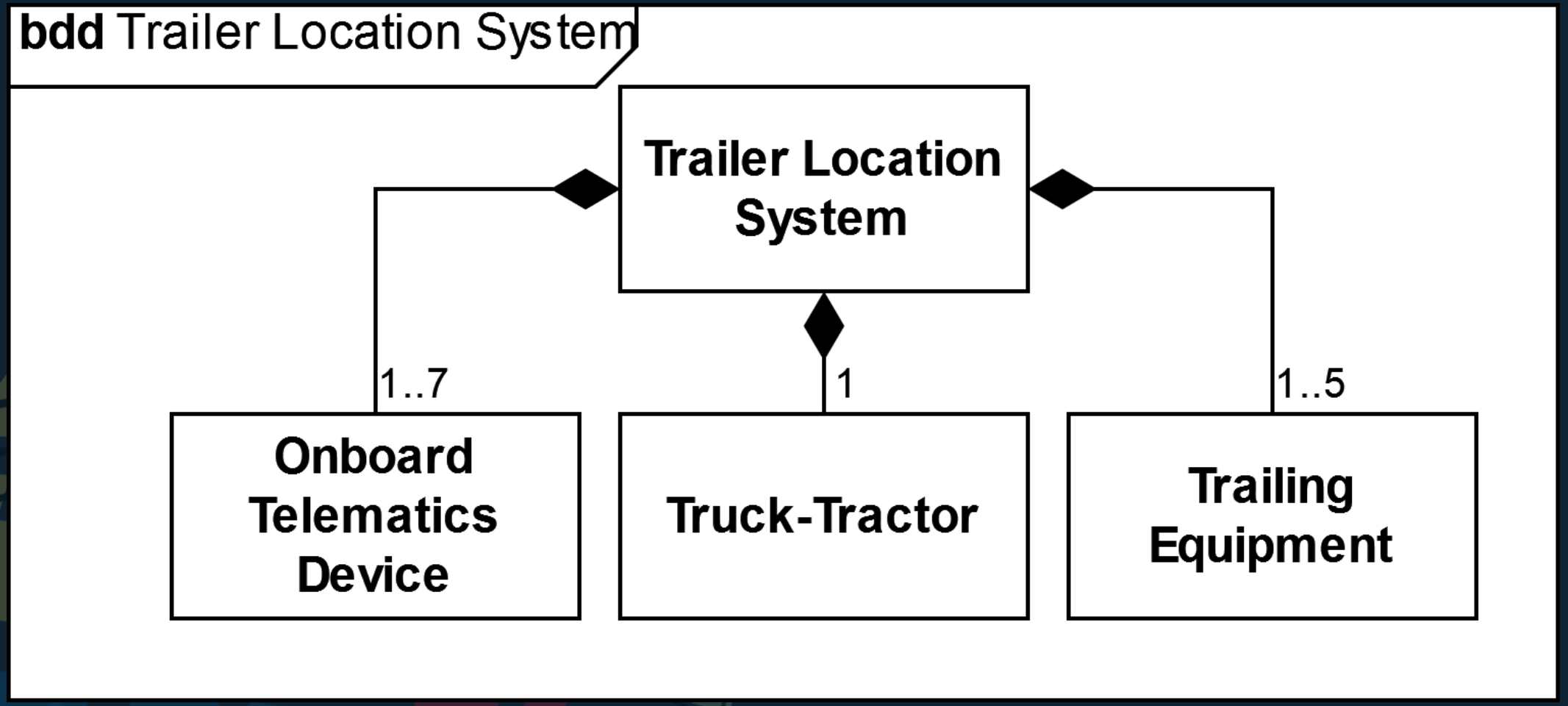


Figure 4: Functional flow block diagram for the system showing three functional levels

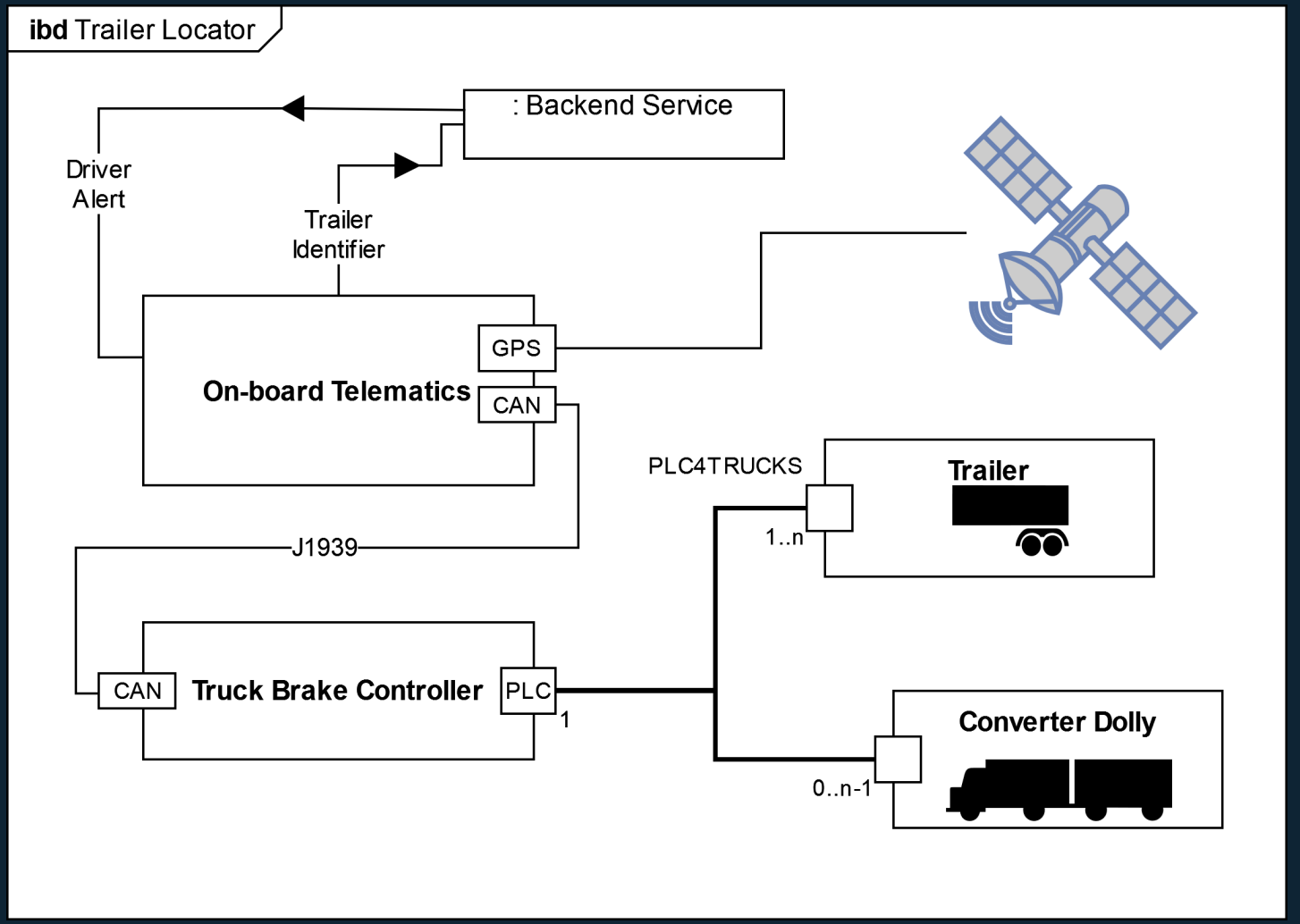
Trailer Location System Block Definition Diagram



Internal Block Diagram

Key Information

- Communications Systems
  - Backend Service
  - Telematics
  - Trailer
  - Tractor



Mission Analysis

System Requirements

System Requirements

Four Key Requirements

1. The system shall locate trailing equipment within 10 meters of accuracy when connected to a truck-tractor.
2. The system shall uniquely identify trailing equipment automatically.
3. The system shall be able to communicate with the transportation management system (TMS) accessible by fleet operators.
4. The system shall work with existing fleet hardware manufactured after March 1, 1998 that is compliant with NHTSA Safety Standard 121

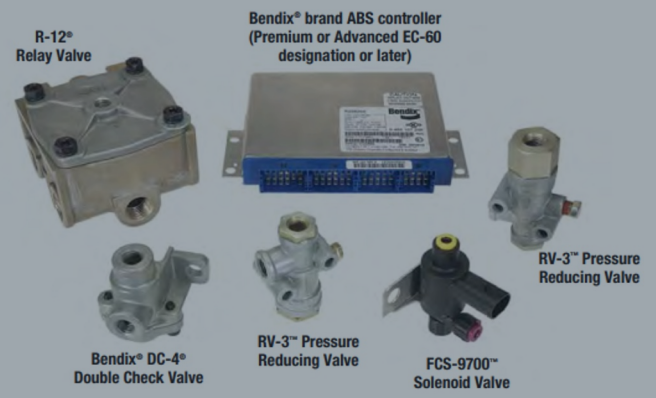
Brake Controller System

Bendix® eTrac™ Automated Air Pressure Transfer System

Automated air bag transfer system.

SD-13-21021

Bendix® eTrac™ Contents	
Service Pc. No.	Bendix® Component
—	Bendix ABS Controller
K082319	FCS-9700™ Solenoid Valve
K035170	R-12® Relay Valve
K082298	RV-3™ Pressure Reducing Valve
101845	
278614	Double Check Valve



106 Bendix

https://www.bendixvrc.com/ecatalog/BW1114_US_010.pdf

Mission Analysis

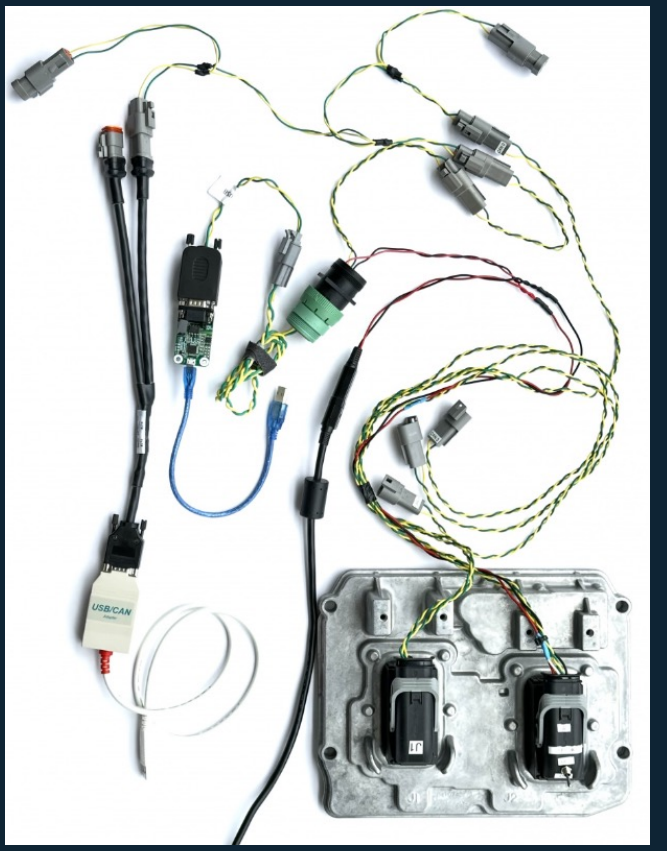
Operational Feasibility Analysis

Implementation Feasibility

- Telematics service providers (TSPs) are motivated by competition
  - Fleets can get TSPs to customize their programming
- Multiple brake control modules use coordinated communications
  - Trailer data can be attributed

Assumptions for Prototype

- TSPs will be able request and receive data
- All trailing equipment will respond correctly over the network
- All trailing equipment has a unique identifier already available the mandatory brake controller.



https://www.cybertruckchallenge.org/past-challenges/2021-2/

Motivation for Prototype Function

TSP Provides Service

Competitive Pressure

Brake ECU Translates

SAE J1939

PLC for Trucks Communicates

SAE J2497

Brake Controller Check-in

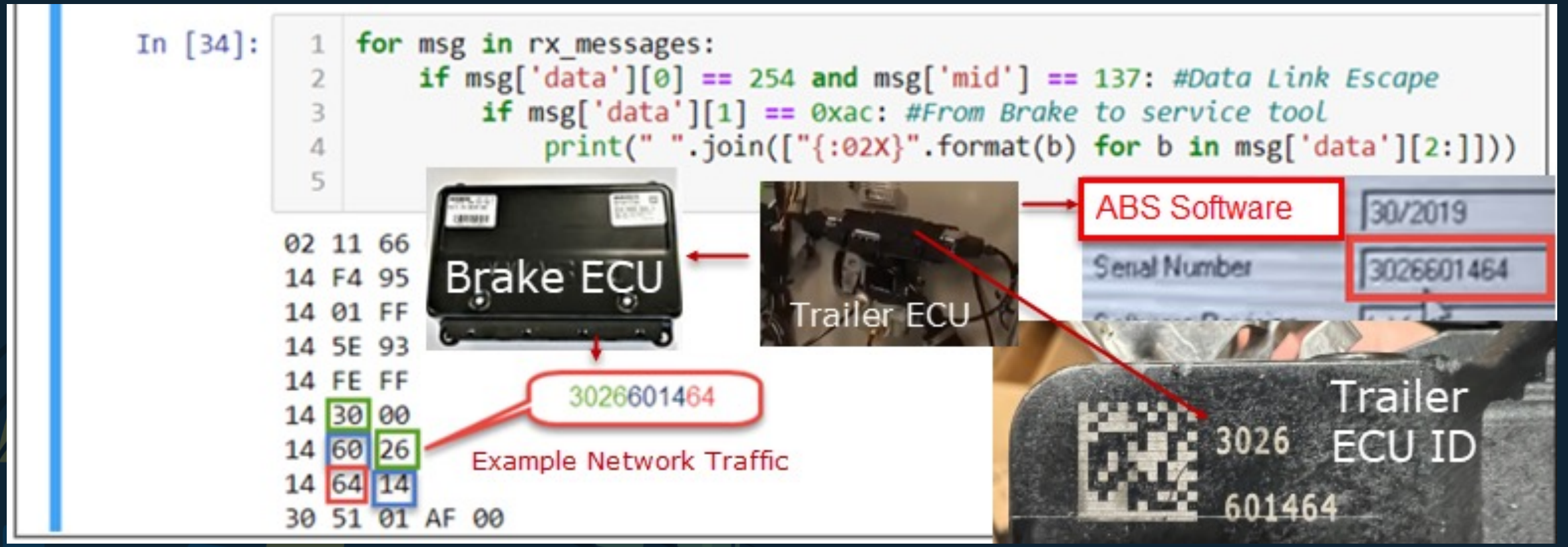
Brake Controller Authentication and System Check, sans light ABS Brake Light

Acronyms
TSP = Telematics Service Provider
ECU = Electronic Control Unit
PLC = Power Line Conversion
ABS = Anti-Lock Brake System

The Prototype

System Implementation on a Prototype

Pictures of the Prototype

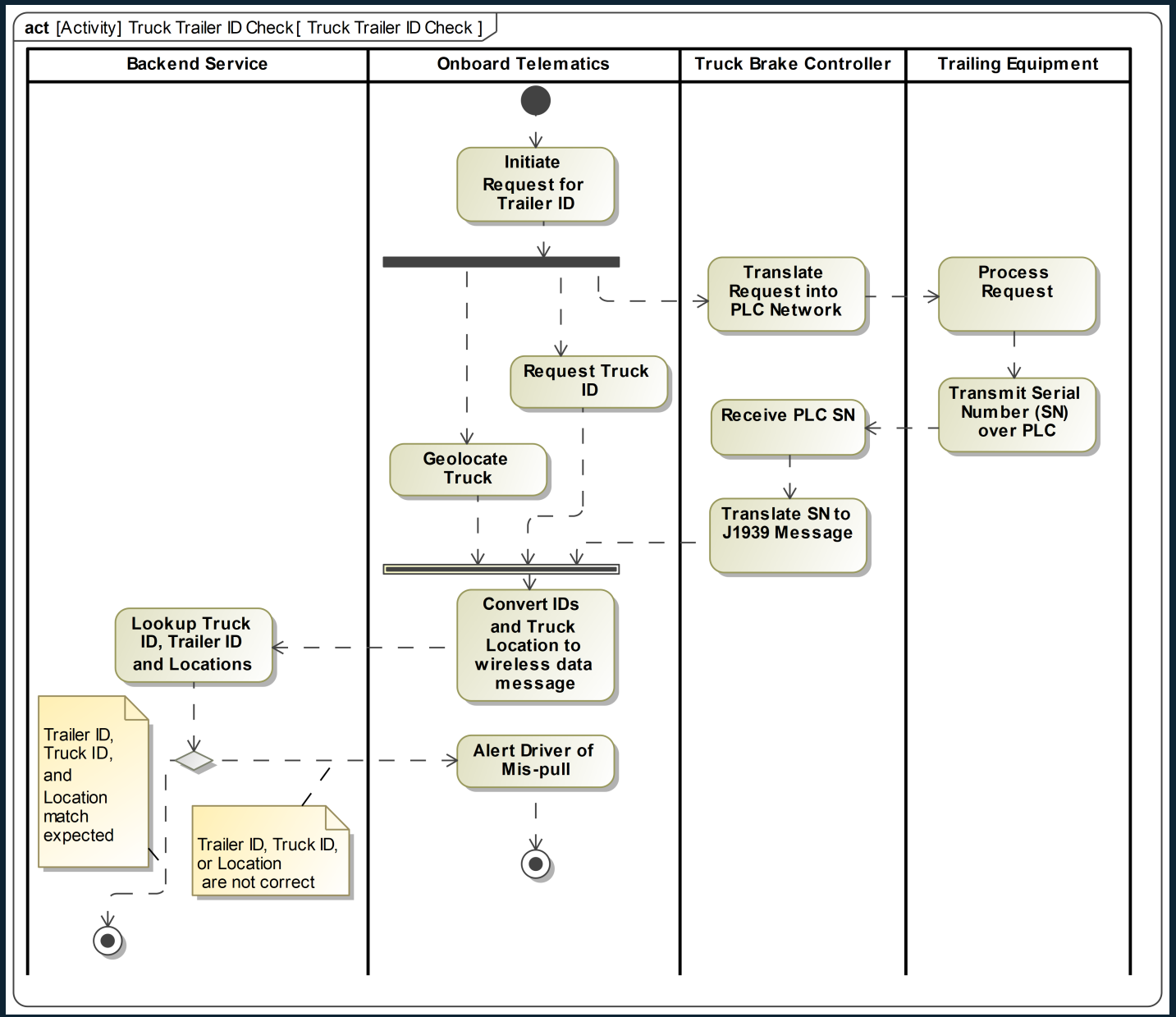


Mission Analysis

Design Definition

Trailer Location System Activity Diagram

- Inspired by a proof-of-concept prototype
- Used existing technologies on the trucks and trailers
- Provided uniqueness from the serial number of the trailer brake system



Prototype Communications Assessment

Telematics Request

Truck Communication

Trailing Equipment Responds

Multiple trailing equipment prioritizes

Brake Controller Checks in with ID

Table 2 - Requirements V&V Matrix

Verification and Validation

Trailer Locating System Requirements	Verification Method	Validation Method	Results
R1. Locate Trailing Equipment	Demonstration	Test	Demonstration showed successful capability, further test pending
R2. Identify Trailing Equipment	Demonstration	Test	Demonstrated a successful test on one brand of brake controller, future tests pending on more equipment combinations
R3. Communication with TMS	Analysis	Test	Analysis shows integration is feasible, testing is pending vendor software implementation
R4. NHTSA Compliant Equipment	Inspection	Demonstration	Fleet inventory demonstrates requirement satisfaction

Conclusions

Continue Development

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Develop a cyber security strategy

Engage Telematics Service Provider (TSP) and Brake Controller Manufacturers

Keep an eye on the future trailer architecture

Risk mitigate driver safety and freight security

Deploy

The People Behind the Project

Acknowledgements

Acknowledgements

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