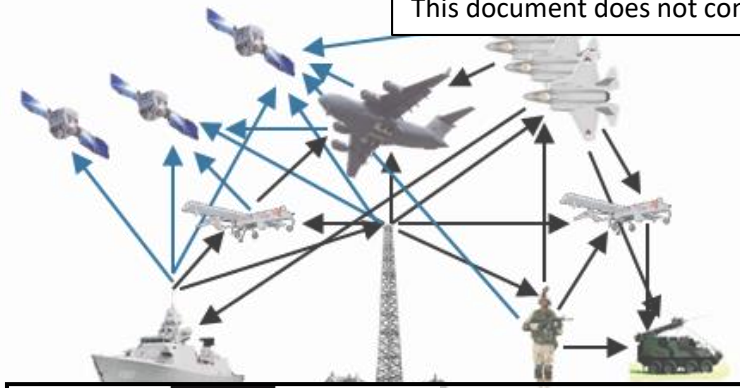
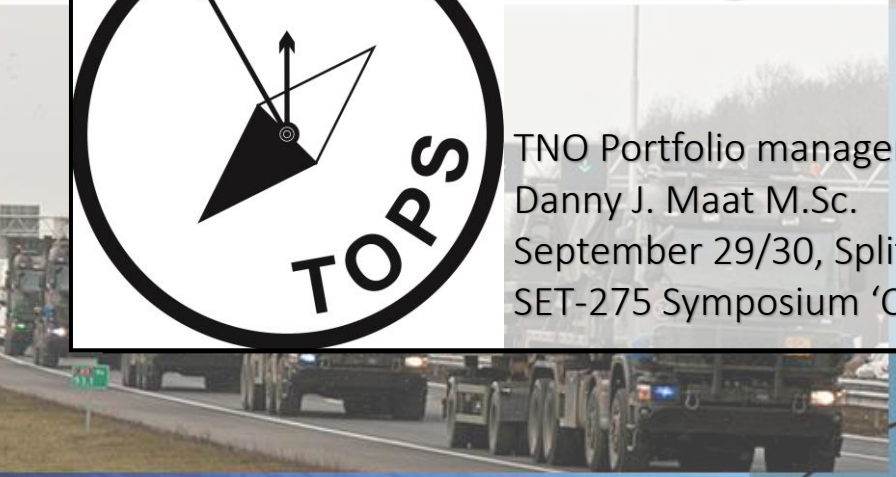
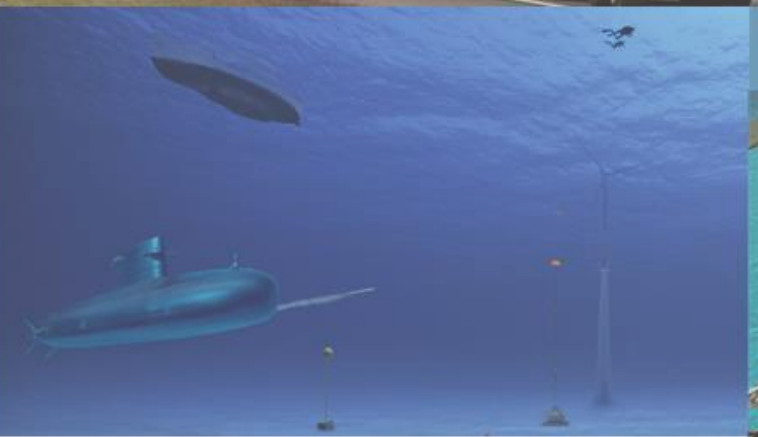
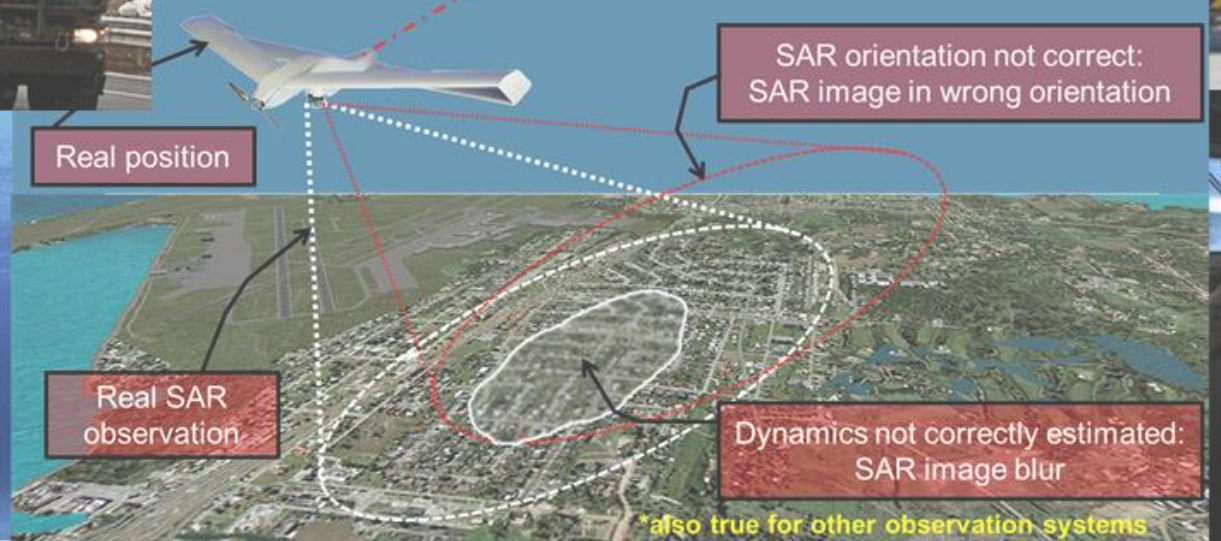


# Timing, Orientation & Positioning Service (TOPS)

TNO Portfolio manager PNT
Danny J. Maat M.Sc.
September 29/30, Split-Croatia
SET-275 Symposium 'Cooperative Navigation in GNSS Degraded and Denied Environments'








# BACKGROUND OF ME IN A NUTSHELL



TNO innovation for life

- 1989 – 1994: Graduated cum laude master electrical engineer

TU Delft
Delft University of Technology

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Oude Waalsdorperweg 63
2597 AK The Hague
The Netherlands

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+31 6 51 54 22 50

- 1994 – 1996: Scantech B.V. / TU Delft
  - Fuzzy logic in bar code decoding
  - Patent NL9500597A
- 1997 – now: TNO
  - **Portfolio manager PNT since 2010**
  - Program manager
  - Project leader
  - Technical project leader
  - Quotation manager
  - Software system architect
- Research fields
  - PNT
  - Intelligent Autonomous Systems
  - Bird Radar (spin out ROBIN Radar Systems)
  - Semantic networks
  - Expert Systems
  - Nuclear, Biologic, Chemical & Damage Control

# PROBLEM

- Reliable PNT undeniable for C2- and communication systems
- PNT has foundational role in military domain (MilGPS)


- Assured PNT **cannot** be delivered by Sat-NAV
  - US DoD does not guarantee availability GPS
  - MilGPS vulnerable for jamming
  - **GNSS becomes more robust, but stay vulnerable**


- Challenges
  - No single sensor system provides assured-PNT
  - No single set operational conditions
  - Different sensor options for every vehicle type



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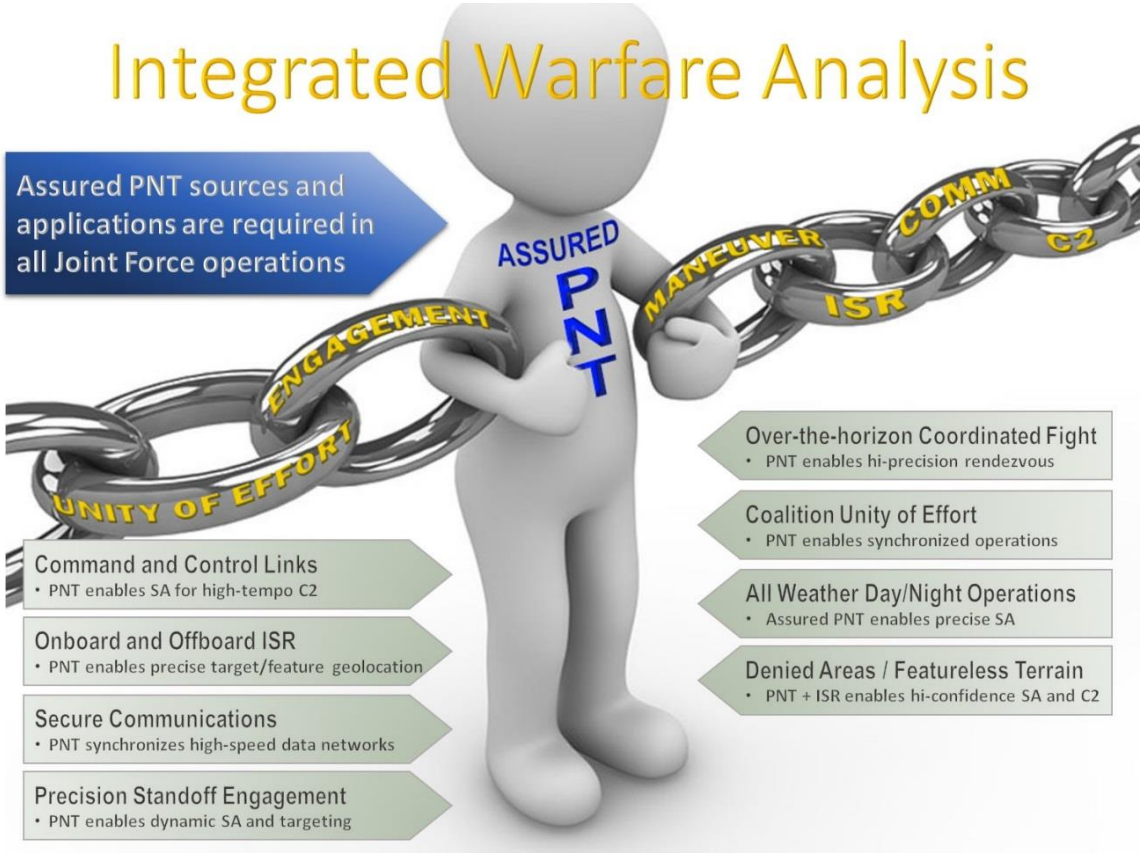
# POINTS OF ATTENTIONS



- Solution has three parts:
  - Sensors
  - Sensor processing
  - The fusion
- Products delivered by industry
  - Often knowledge about one sensor technology
  - Black box
  - Standardization
  - Vendor lock-in
- Why is sensor fusion difficult?
  - Sensor have many types of error sources
  - Sensor models and platform models not perfect
  - Integration of multiple algorithms necessary




*Picture from NATO navigation Warfare (NAVWAR) Playbook, d.d. 22-02-2021*



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# TOPS INTRODUCTION

## Integrated, robust & validated PNT-solution needed

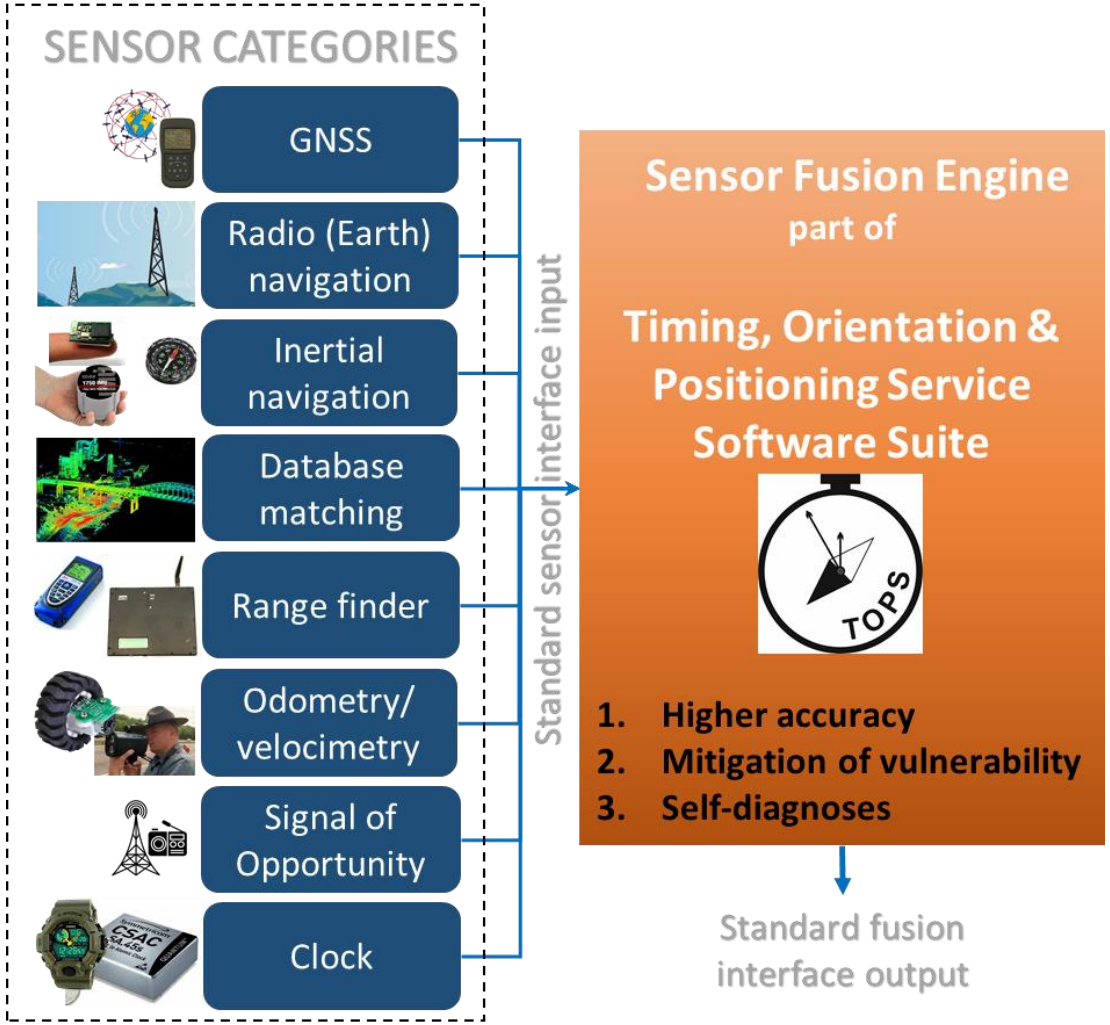
- Minimize vulnerability (avoid single sensor dependency)
- Complement strengths & create redundancies
- Higher accuracy PNT estimates (over time)
- Insight in PNT uncertainty

## What can TNO do?

- Determining which sensor to buy
- Innovative sensor processing methods
- Sensor fusion engine (online & offline)
- Testing and validating

## Why TNO?

- Independent & not-for-profit research organization
- In depth knowledge different technologies
- Defence laboratory



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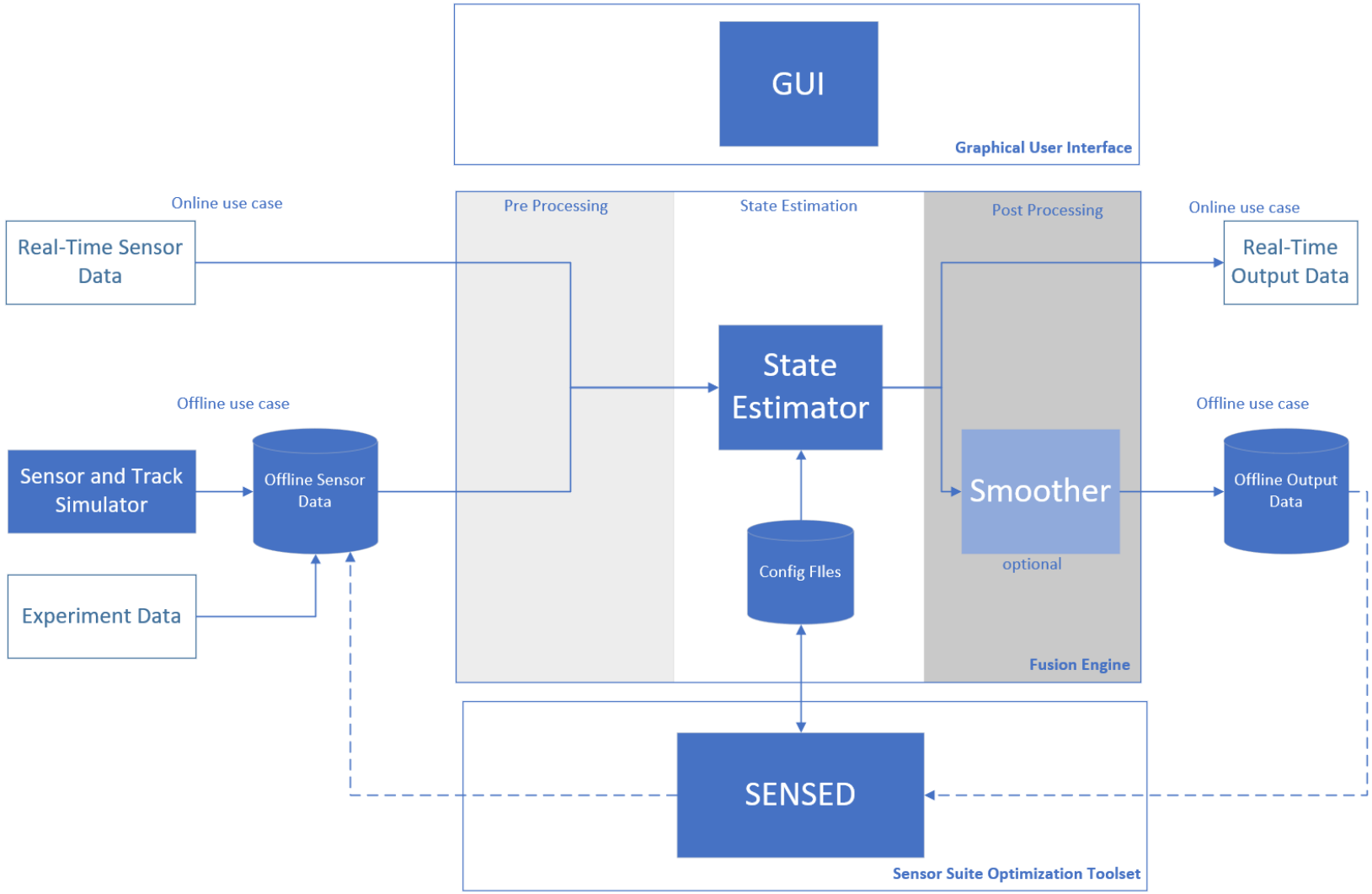
# TOPS OVERVIEW






- **TOPS Software suite**
  - Modular C++ sensor fusion framework
  - Single SW base to deploy and maintain
  - Focus on quality & performance
- **Fusion engine**
  - Highly configurable
  - Real-time (operational)
  - Off line analyzing
  - Pre processing (e.g. integrity)
- **GUI**
  - Research
  - Operational
  - Maintenance
- **Sensor Suite Optimization Toolset**
  - **S**imulation **EN**hanced **SE**nsor **D**esign
  - Which sensor to buy? Not trivial!



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# TOPS FUSION ENGINE



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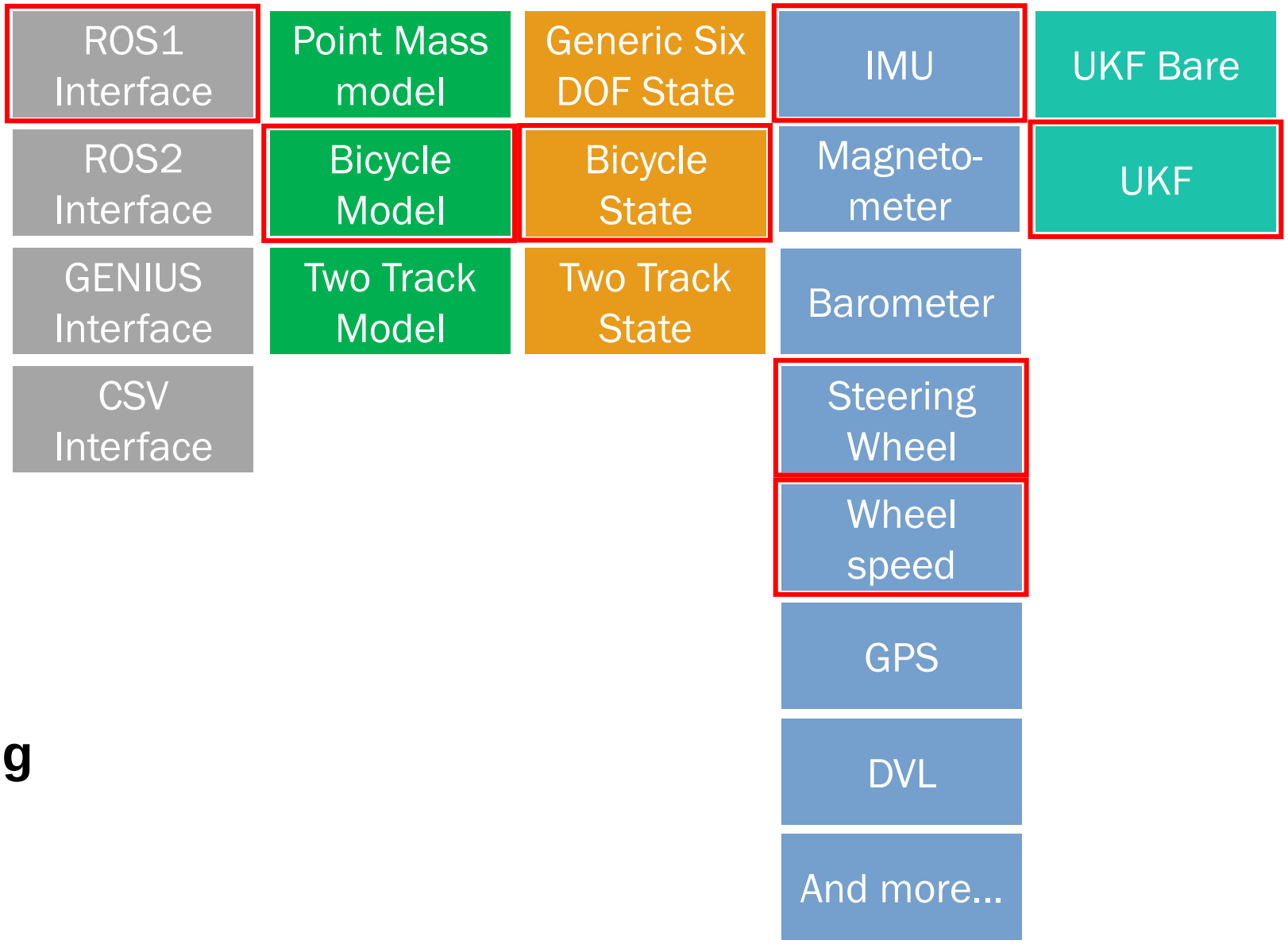
- Configurable based on needs
- Selectable predefined components
  - Filter interface
  - Plant model
  - State
  - Sensor model
  - Kalman filter
- **TOPS toolbox keeps growing**



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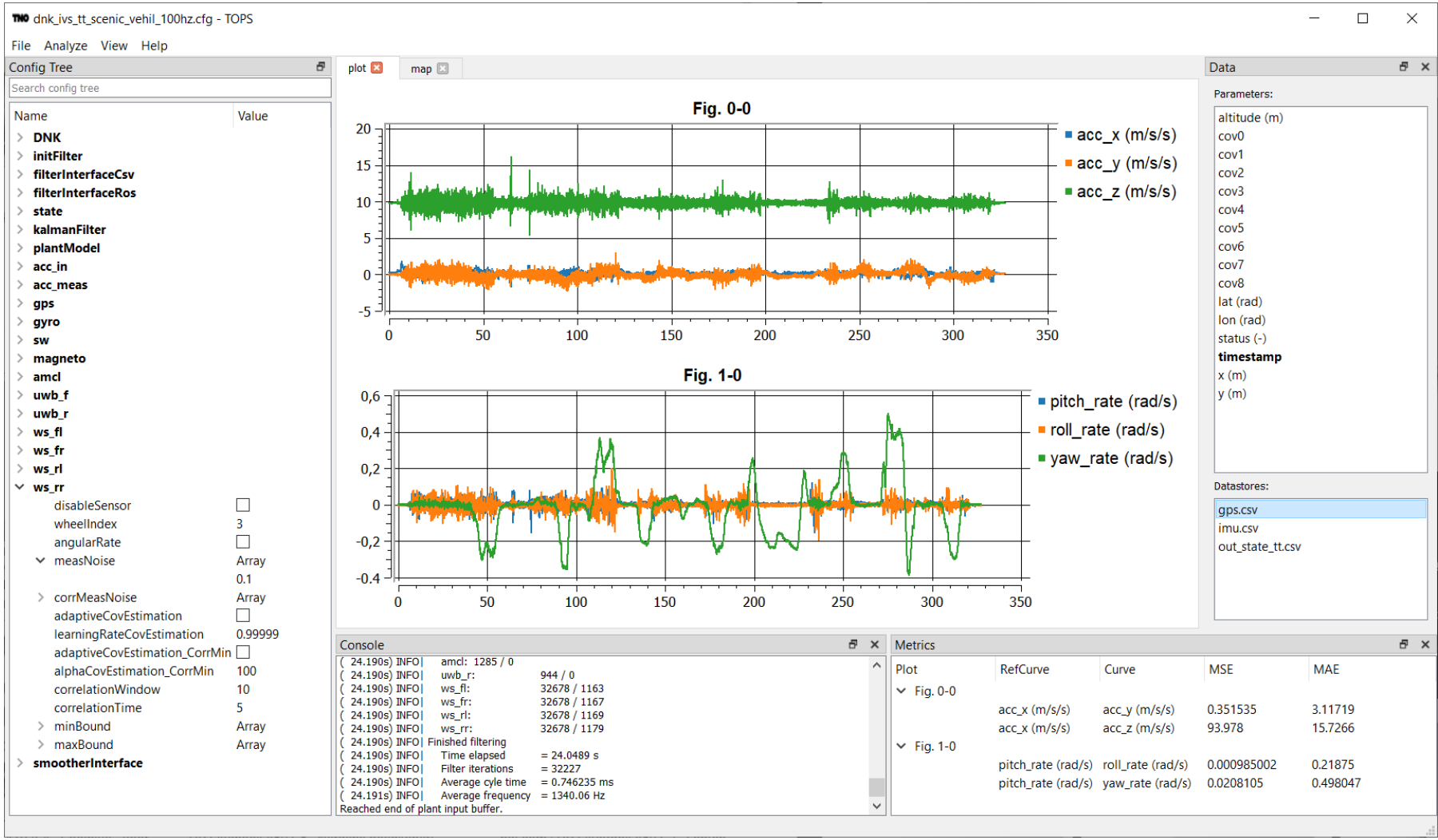
# TOPS GUI



- Research tool
  - Configuration & tuning
  - Sensor analysis
  - Run state estimator
  - Results analysis
  - Online/offline use case
- Maintenance tool
- Operational tool



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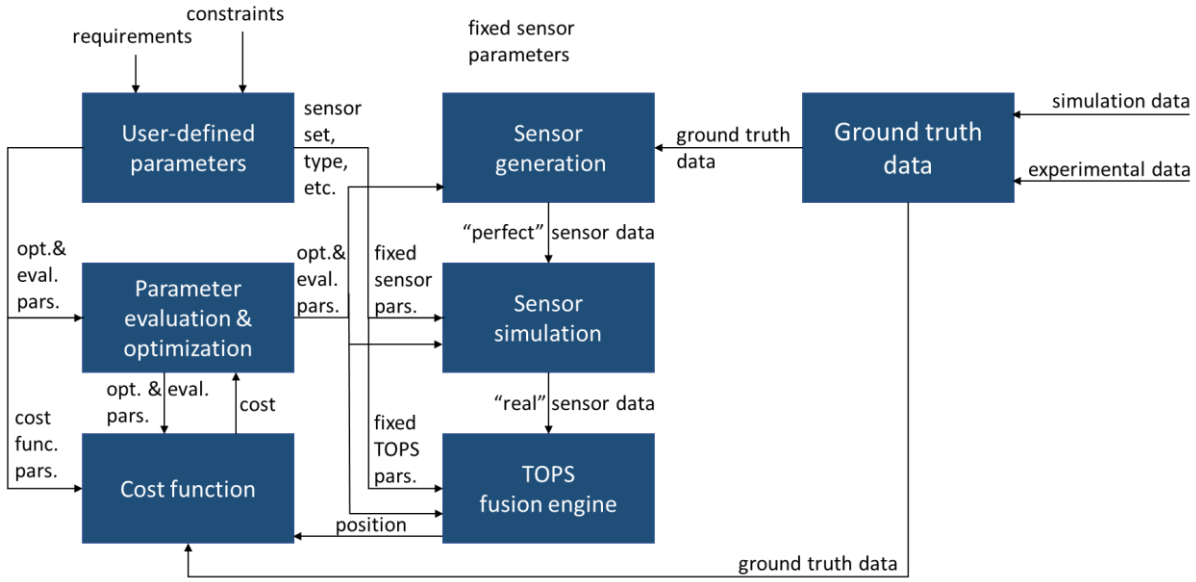
# TOPS - SENSED



- Problem and functional gap: reasoning from requirement to sensors difficult

- **S**imulation **EN**hanced **SE**nsor **D**esigner
  - Sensor (suite) designer/optimizer with TOPS
  - Monte-Carlo-style verification




- Why SENSED?
  - Design & sensor optimizer
  - Optimize parameters for cost and requirements
  - Evaluate user-defined parameters
  - Sensitivity analysis



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# RESULTS LAND BASED USE CASE 1/2



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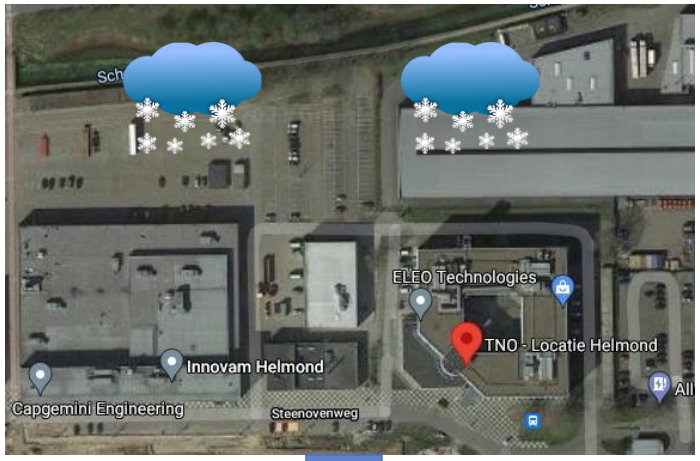
- Subsidy project in cooperation with automotive TNO – Helmond
  - Autonomous driving on bus depot
  - Indoor/outdoor driving
  - Development high fidelity vehicle model
  - Research into GPS replacements
    - UWB
    - Lidar SLAM
    - Laser scan matching
- Differences military vs civil test case
  - GPS-denied environment
  - Off-road
  - Operations at night time





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# RESULTS LAND BASED USE CASE 2/2



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- TOPS sensor fusion suite
  - Vehicle model
  - IMU
  - Steer angle
  - Wheel speeds
- 15 minute data set
- Maximum error: 20 meter
- **Very good!!**




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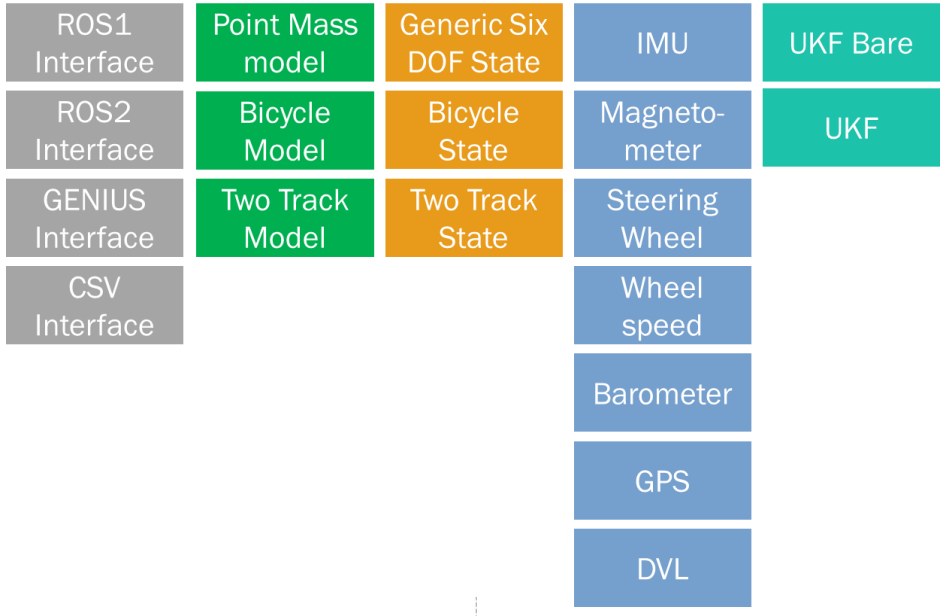
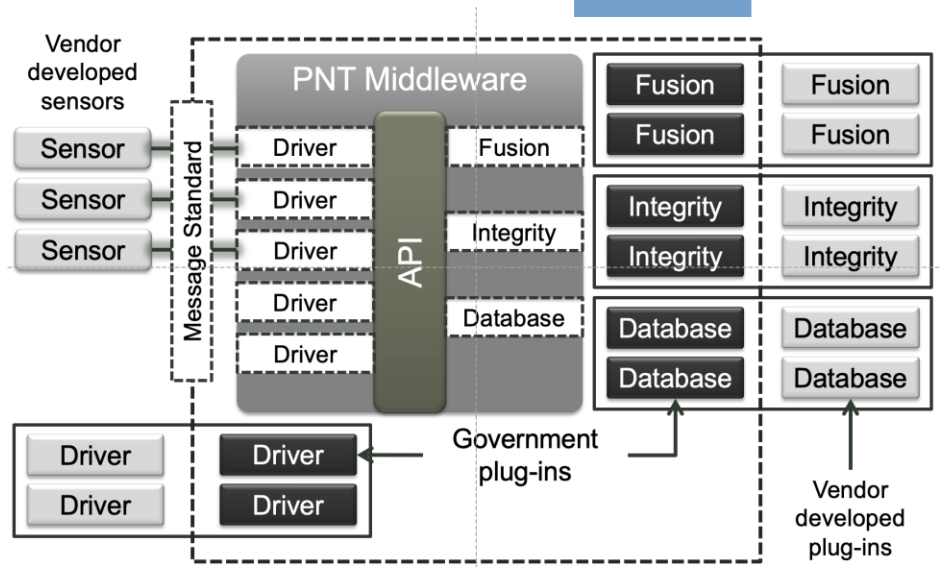
# CONCLUSION AND FUTURE DEV.



TNO innovation for life

- **TOPS proofs a successful framework, toolkit and service**!
- **Operational service (white box) for Defence** & Safety partners
- TOPS continue to improve and functionality added
  - Sensor fusion: platform model enhancements
  - User-friendly GUI for operational (& maintenance) usage
  - Indicator for sensor input and fusion output quality
- Research & provision for new disruptive technologies
  - Quantum sensors can boost gravity gradiometry
  - Effect of new technology (TOPS - SENSED)
- Cooperation and standardization
  - NATO RTG (SET-309)
  - Standardization sensor input and PNT-info output



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