ASAM OpenX Standards for Offroad Applications

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ASAM Technical Seminar

ASAM Association for Standardization of Automation and Measuring Systems

Agenda

- Motivation for the Activity
- Operating in the Offroad Environment
  - Use Cases
  - Scenarios
  - Challenges
- ASAM OpenX Standards in Offroad Applications Project
  - Timeline
  - Activities
  - Early Thoughts

Motivation for the Activity

Offroad Applications

- Landfill
- Construction
- Agriculture
- Mining
- Military
- Recreational
- Other
  - Forestry
  - Space
  - Warehouses
  - Harbors
  - Maritime

Use Cases Driven by Personas

- What kind of simulations do users want to build for offroad applications?

Vehicle Developer

- Develop and test mechanical, electrical, hydraulic, and electro-mechanical systems for offroad scenarios
- Build **physics-based vehicle models to test vehicle behavior** in 3D simulations

Autonomy Developer

- **Create algorithms**, software and supporting documentation for perception, planning and control of the vehicles and their support tools
- Collect **sensor and mobility data** for training AI/ML models
- Work with control engineers to investigate, **test**, and select **software toolsets or hardware components** and peripherals

Test Engineer

- Develop and **evaluate detailed offroad test scenarios for both component and system level testing and validation**.

System Integration Engineer

- Create scenarios to help **understand the requirements** for systems.
- Create schematic representations of mechanical, electrical, hydraulic, and electro-mechanical systems
- Work with other disciplines to create the specifications that outline the **control system logic** necessary for haul truck functions

Site Manager

- Manage and assess the **application of vehicle systems on-site**.
- Work with the environment, health, and safety teams and security teams to **conduct regular risk assessments**
- Maintain a risk register and develop and implement risk mitigation plans

Technical Requirements Driven by Use Cases

Vehicle Developer

- Represent vehicle components relevant to **VTI/mobility**
- Represent driveline/powertrain for the vehicle
- Modelling of **heavy machinery on soft terrain** (deep tracks)
- Represent vehicle loads including specification of type and volume of material being transported and estimating effects caused by the load **including stability, traction, deformation of road surfaces, and maneuverability**
- Evaluate or optimize efficiency of vehicle systems

Autonomy Developer

- Model vehicle perception and **mobility and dynamics** as it traverses an offroad environment
- Model GPS **sensor data** accounting for effects of vehicle movement, terrain, and vegetation including loss of signal, multipath, etc.
- Model common sensors (e.g., LiDAR, EO camera, IR, radar, GPR, etc.) accounting for effects of **vehicle movement, terrain, and vegetation including occlusion, material attribution**, etc.

Test Engineer

- Evaluate or optimize efficiency of vehicle systems in the operating environment
- Represent **effects of adverse conditions** (dust, standing water, mud, etc.) on terrain properties and on sensors (e.g., occlusions from dust clouds, water spray, water or mud on lenses, etc.)
- Estimate **effects of vegetation** on sensors and vehicle mobility
- Extract sensing and mobility data for learning how to traverse terrain

System Integration Engineer

- Generate prior information to the autonomy stack (e.g., simulate extraction of maps, etc. from previous drives, UAS, or other sources)
- **Represent vehicle loads** including specification of type and volume of material being transported and estimating effects caused by the load including stability, traction, deformation of road surfaces, and maneuverability
- Share and reuse off-road scenarios in a common format for shared understanding

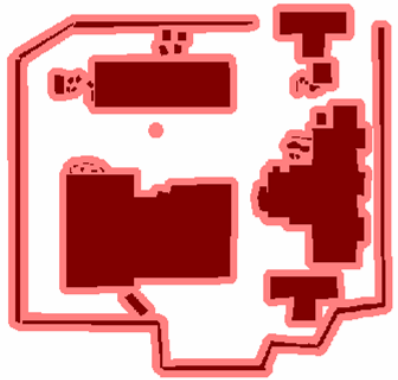
Site Manager

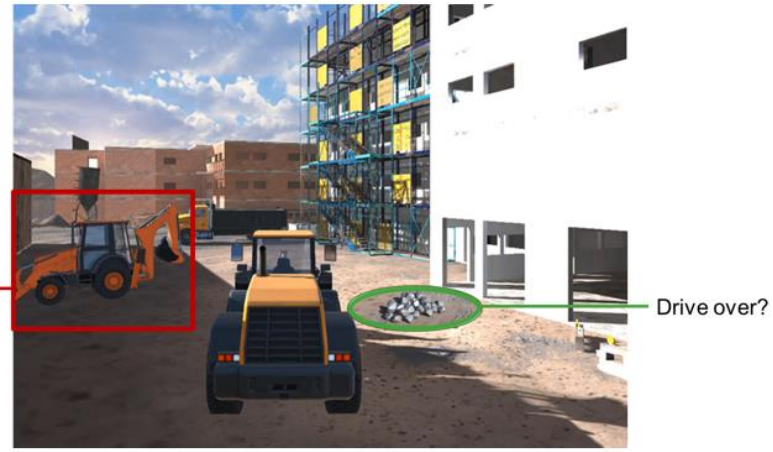
- Incorporate fuel depot/charging stations (capacity, charge/refuel rate)
- Collecting performance data for benchmarking systems

Operations and Activities

Categorizing activities

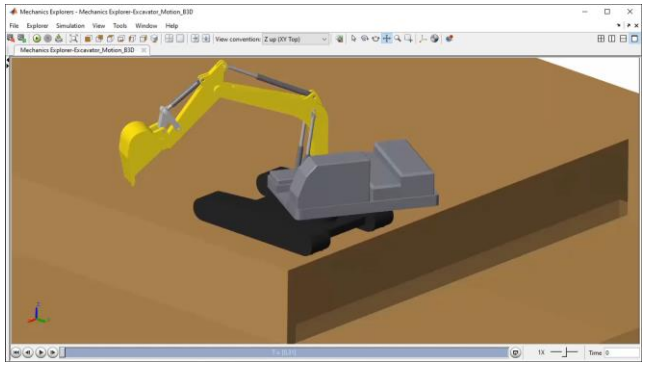
Vehicle Movement





- Navigation
- Vehicle-terrain interaction
- Interaction with objects

Manipulating the Environment



Excavating a pit

Manipulating material

Loading a vehicle

Excavator Simulation Model - https://www.mathworks.com/matlabcentral/fileexchange/119268-excavator-design-with-simscape

MathWorks Webinar on "Design and Simulating Autonomy for Construction Vehicles", https://www.mathworks.com/videos/design-and-simulating-autonomy-for-construction-vehicles-1679066541903.html

Kaibab National Forest, 2019,[Grassland Restoration 2019(48867911186).jpg][Photograph], https://commons.wikimedia.org/wiki/File:Grassland_Restoration_2019_(48867911186).jpg, CC-BY-SA-4.0.

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Scenarios

Moving from Point A to Point B

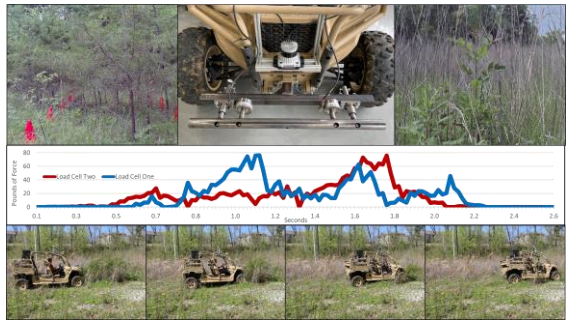
1. **Following a Path**
2. Finding a Path
3. Carrying a Load
4. Using Sensors to Respond to the Environment
5. Navigating without GPS

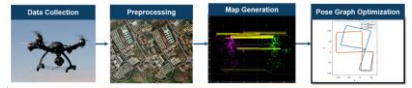
Vehicle Interaction

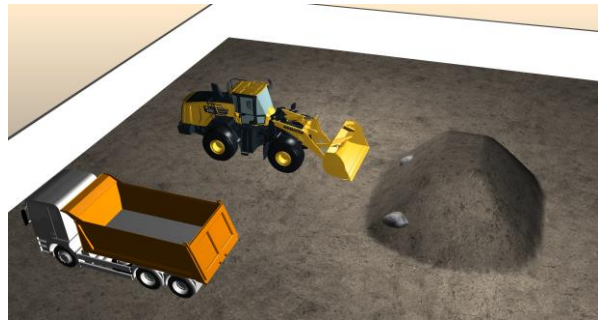
6. Following a Lead Vehicle
7. Dealing with Environmental Effects
8. Interacting with Traffic
9. Incorporating Drones / Ground-Air Vehicle Teaming

Load and Haul

10. **Loading a Hauler - Hauler**
11. **Loading a Hauler – Excavator**
12. Evaluating fuel efficiency







R. Luck, 2011.[Caterpillar haul truck, Luminant Energy Kosse lignite mine][Photograph]. https://www.flickr.com/photos/roylluck/5556779421/, CC-

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Offroad Challenges

Environment

- Complex 3D terrain
- Soil Properties
  - Soil strength, density, temperature, water content
  - Mobility and excavation
- Object representation
  - Vegetation and other natural obstacles
  - Meshes, materials, physics
- Weather conditions

Sensors

- Sensor modeling and surface materials (including link between appearance and physical characteristics)
- Occlusion of sensors
  - Mud, snow, dirt in the air and on camera lens

Vehicles

- Vehicle-terrain interaction and material dynamics
  - Mud and water spray
  - Mud and snow deformation
  - Accumulation of material on vehicles

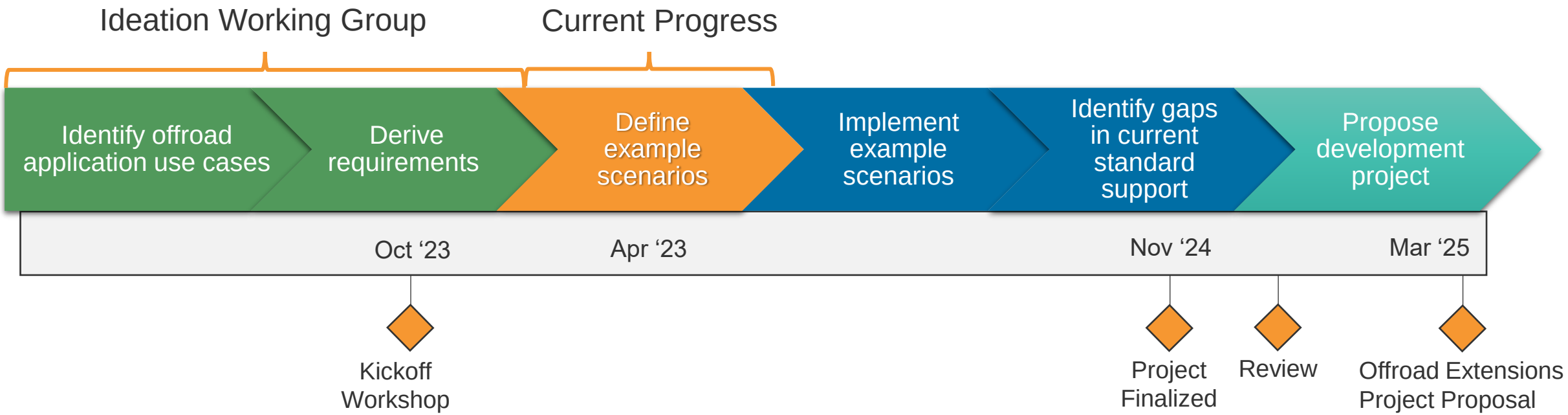
MSU CAVS, 2021, [Mud on camera lens][Photograph], permission from author.

MSU CAVS, 2021, [Mud splatter][Photograph], permission from author.

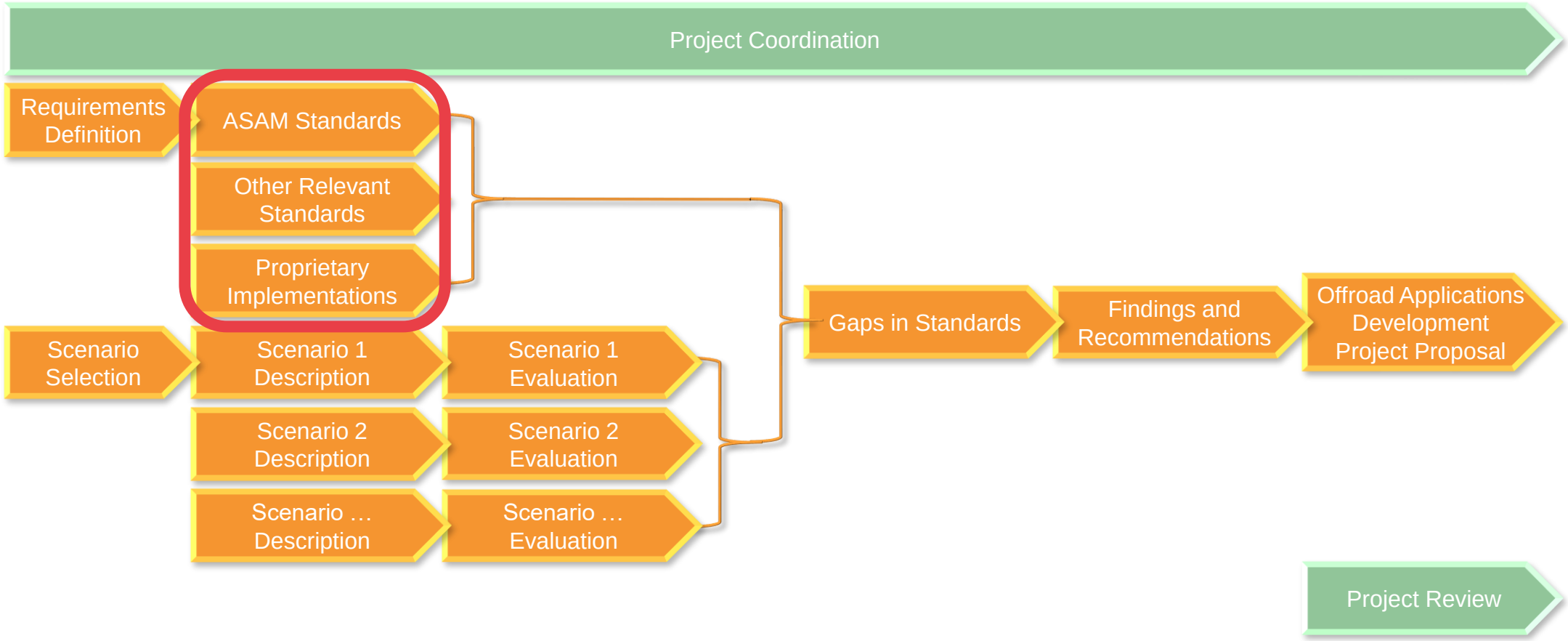
Concept Project ASAM OpenX in Offroad Applications

GOAL

- Evaluate the need for extensions to existing standards or development of new standards to support modeling and simulation of (a) vehicle mobility in off -road conditions and (b) earth moving for digging, loading, and hauling

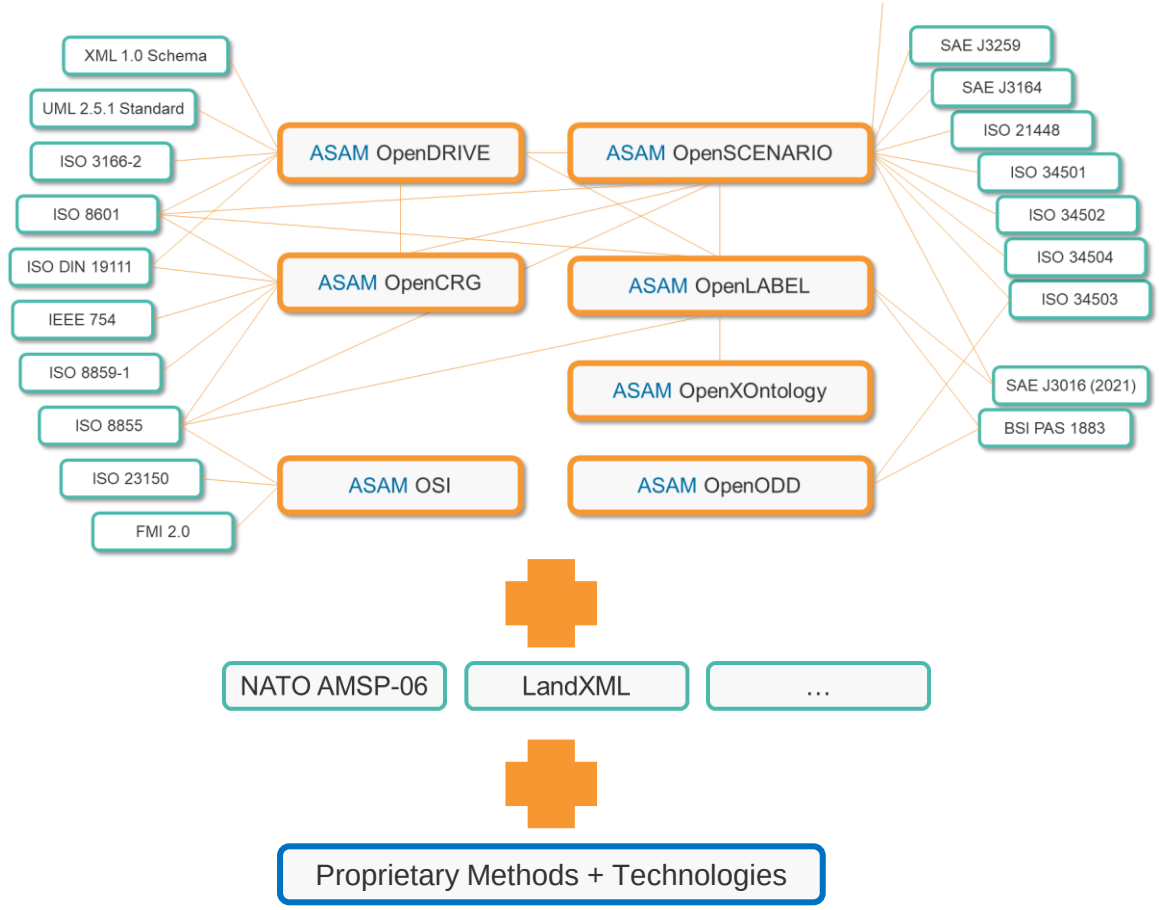


Project Activities



Standards

- ASAM OpenX Simulation Standards
  - OpenCRG
  - OpenDRIVE
  - OpenSCENARIO
  - OSI
  - OpenODD
  - OpenLABEL
  - OpenMATERIAL
  - OpenTEST
- External related standards - Terrain, drivable area, and materials
  - Landxml 1.2 (infra model 4.0.4)
  - ISO 15143-4
  - ISO 7334
  - EMESRT PR5A
  - ISO 21815
  - ISO 6165
  - NATO AMSP-06
- Proprietary solutions
  - e.g., Algoryx agxTerrain implementation



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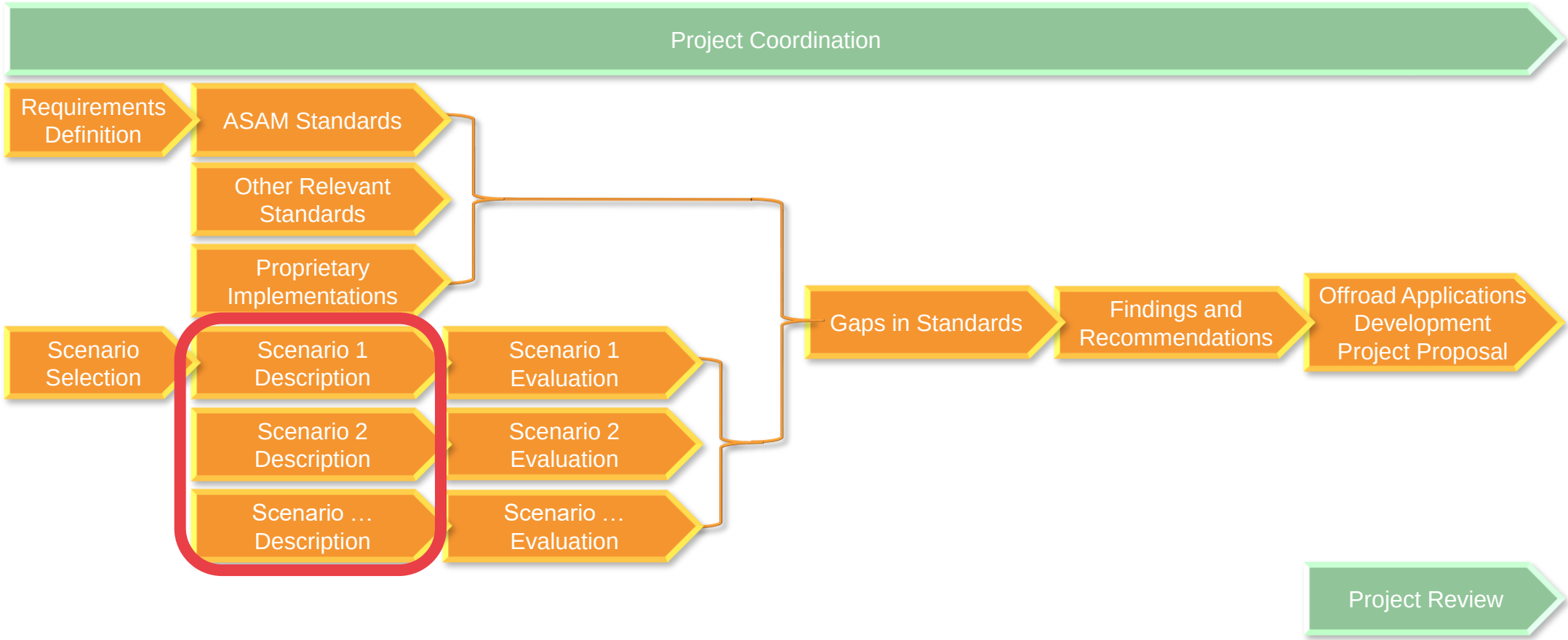
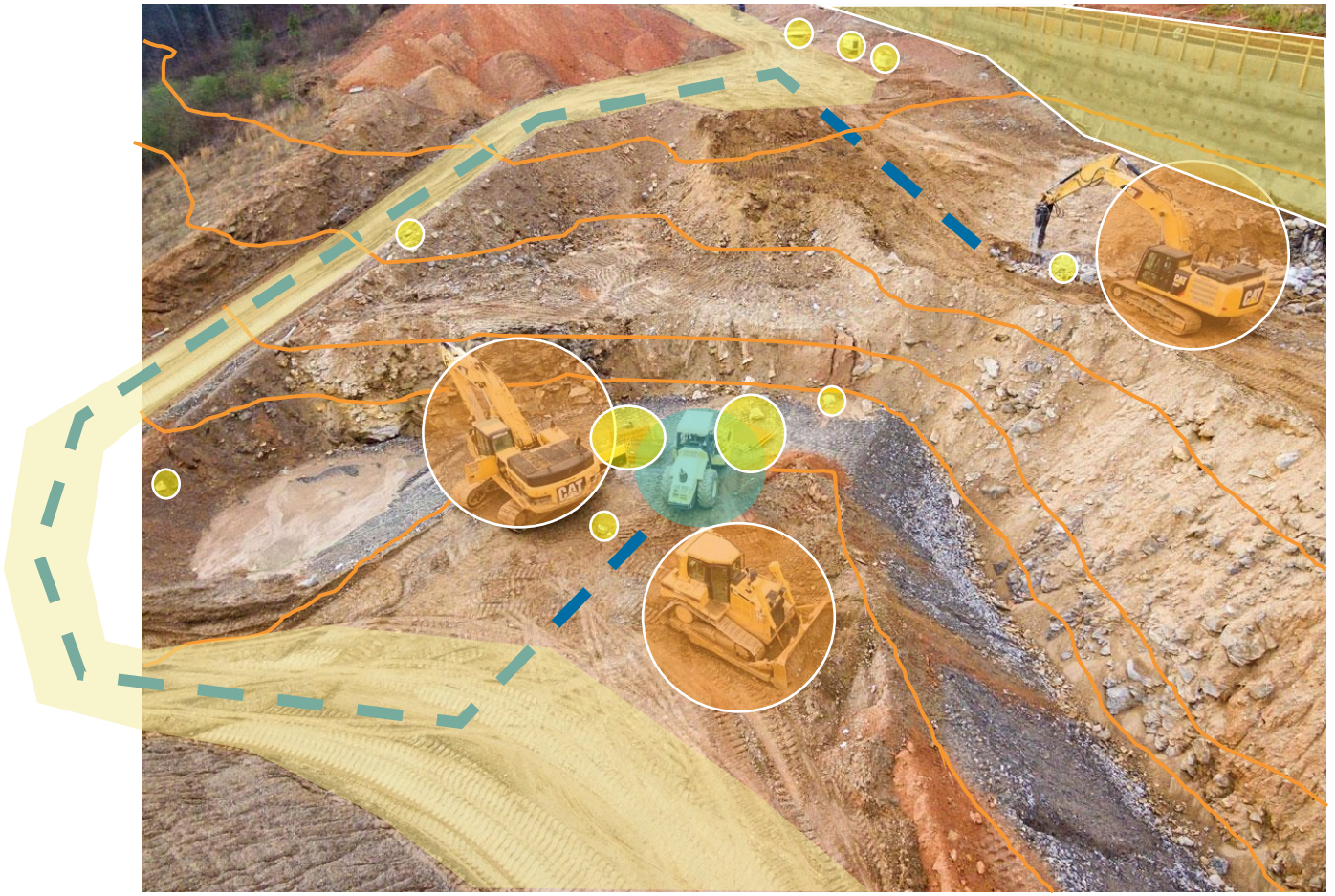


Simple Scenario

Simple Construction Scenario

Scenario Components

- Test Article
  - Vehicle
  - Sensors
  - Hardware
  - Controllers
- Scenario
  - Environment
    - Topography
    - Soil Properties
    - Road
    - Cover
    - Object
    - Agent
    - Conditions
    - Networks
  - Objective



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Heightfields, meshes, and voxel maps

Simple Construction Scenario

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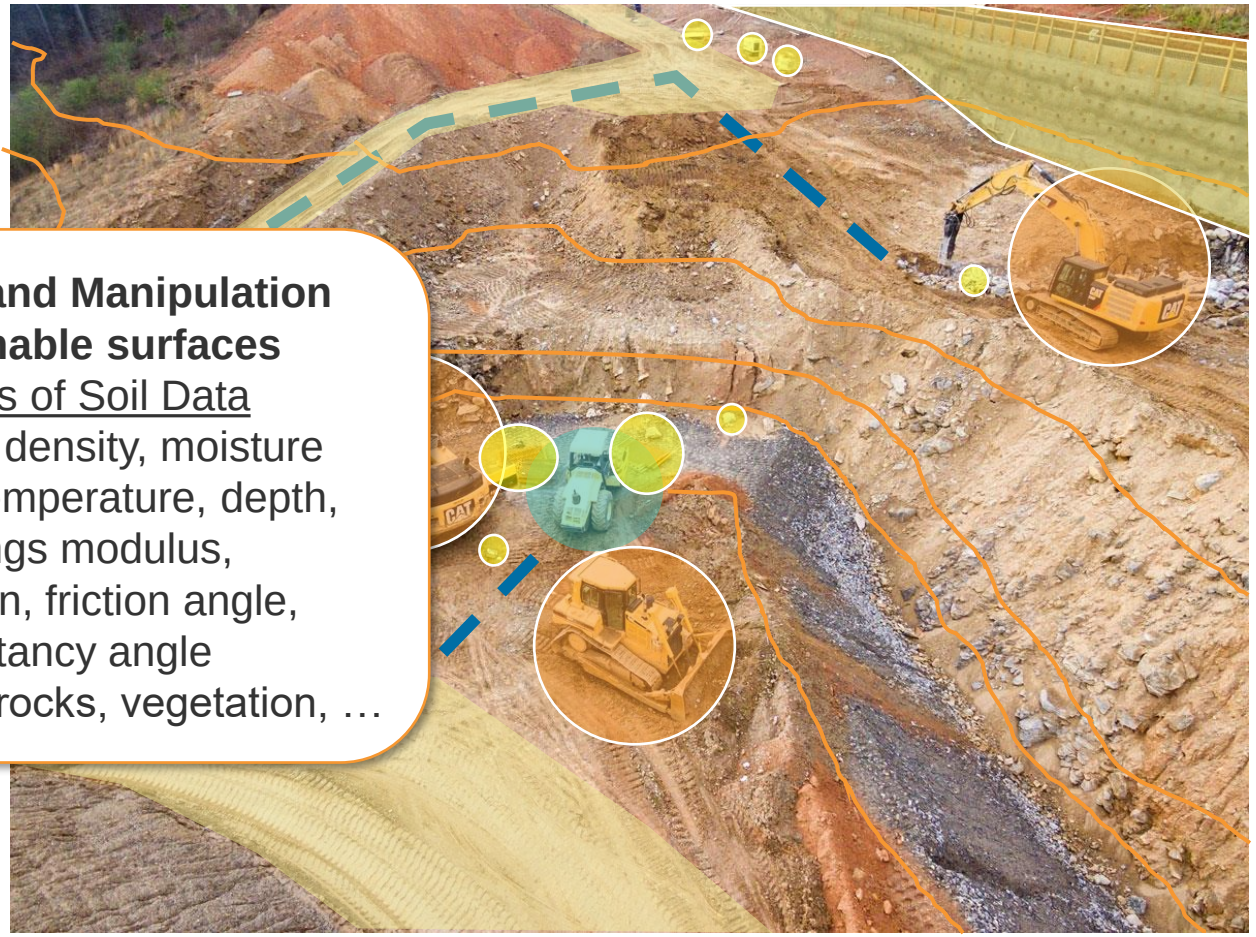
Mobility and Manipulation
Deformable surfaces
Layers of Soil Data
Soil type, density, moisture content, temperature, depth, Youngs modulus, Cohesion, friction angle, dilatancy angle
Inclusions – rocks, vegetation, …



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Physics for Interaction
Dynamic, deformable, breakable objects

Simple Construction Scenario

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Scenario
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Conditions affect the environment, the vehicle, and the sensors

Possible Interaction with Other Standards

- OpenMATERIAL
  - Materials
    - For terrain, cover, objects, agents, …
    - Affected by Conditions – dry, wet, very wet, frozen, etc.
    - Varies by Sensor – visual, IR, LIDAR, RADAR, etc.
    - Affected by state – deformable terrain, snow, etc., ruts in mud, etc.
  - Objects
    - Interactive physics, deformable and breakable objects
      - For terrain, vegetation, objects, …
      - Affected by vehicle interaction, wind, etc.
- OpenDRIVE/OpenCRG?
  - Terrain patches with soil properties
    - For mobility, excavation, …
    - Affected by Conditions
    - Material – Condition Consistency (e.g., wet soil should look wet to cameras)

Vehicle Definitions

Digging into other Scenarios

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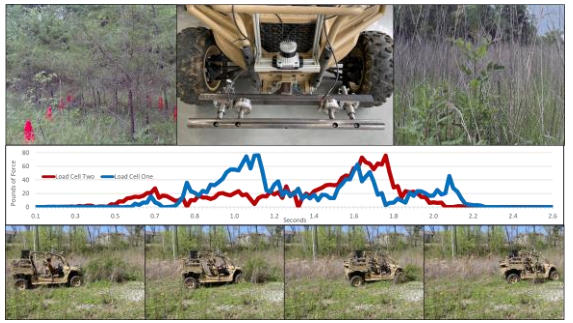

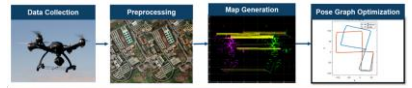

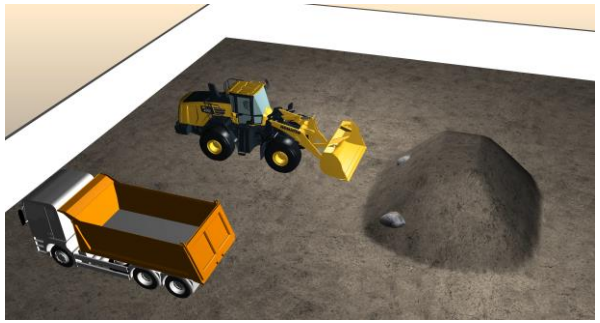

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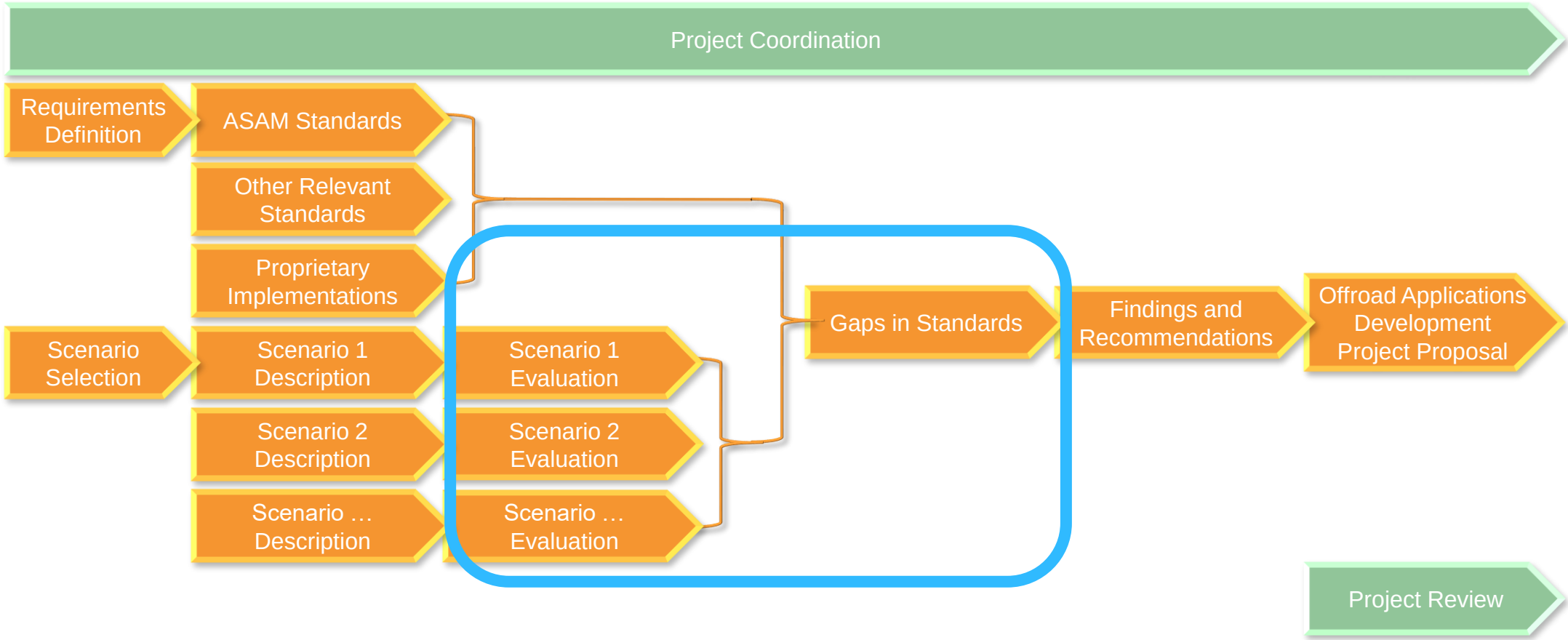
Project Activities

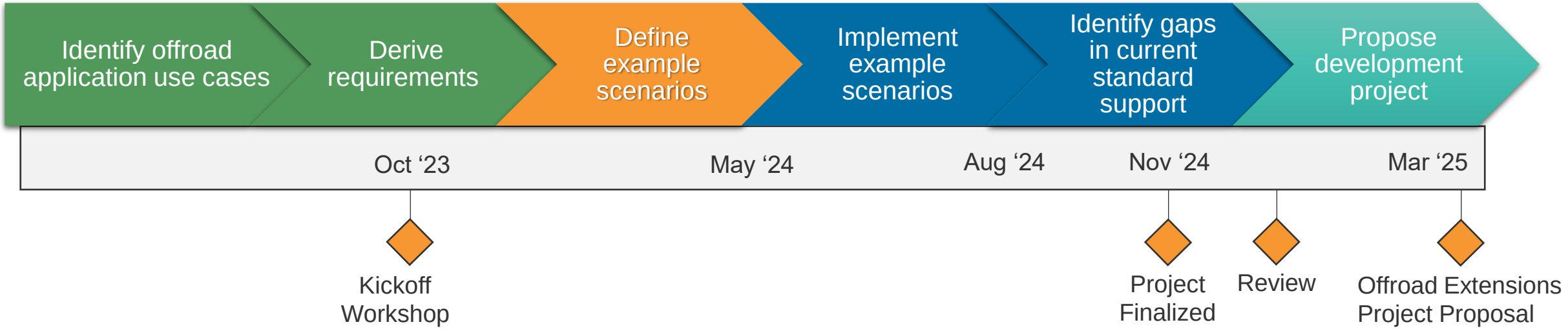
Looking Ahead



ASAM OpenX in Offroad Applications

DELIVERABLES

- Example offroad scenarios and documentation.
  - Documentation of requirements driven by offroad application
  - Evaluation of current ability to meet requirements with current standards
  - Estimate overall level of support for offroad applications
- Create a concept document for extensions and/or standards for supporting offroad applications
- Offroad extension project proposal



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