26th annual INCOSE international symposium

Edinburgh, UK
July 18 - 21, 2016

Getting Started with MBSE in Product Development

Nichole Kass

syncroness™
complex problems inspired solutions

Model-Based Systems Engineering

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MBSE's Promise

- Manage **interconnectedness** of project elements
- Improve **communication**
- Increase **productivity** and **quality**
- **Reduce risk**

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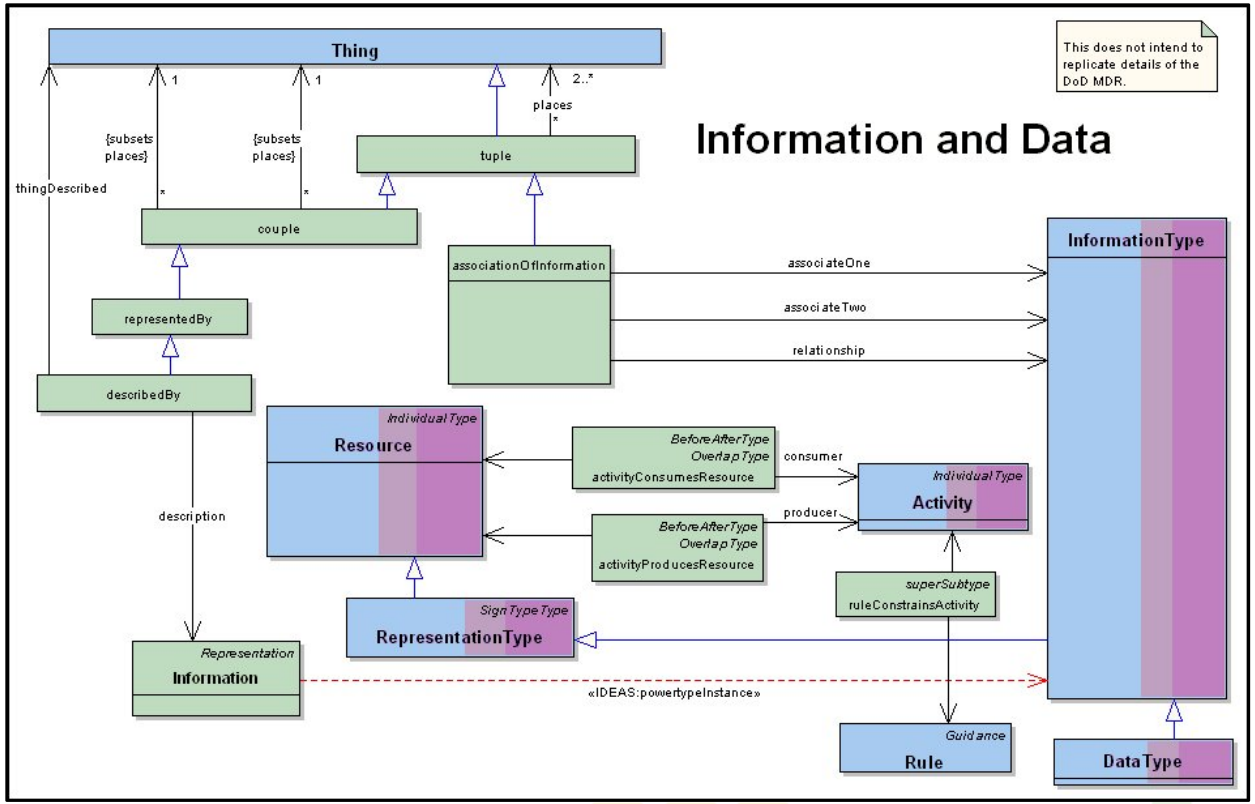
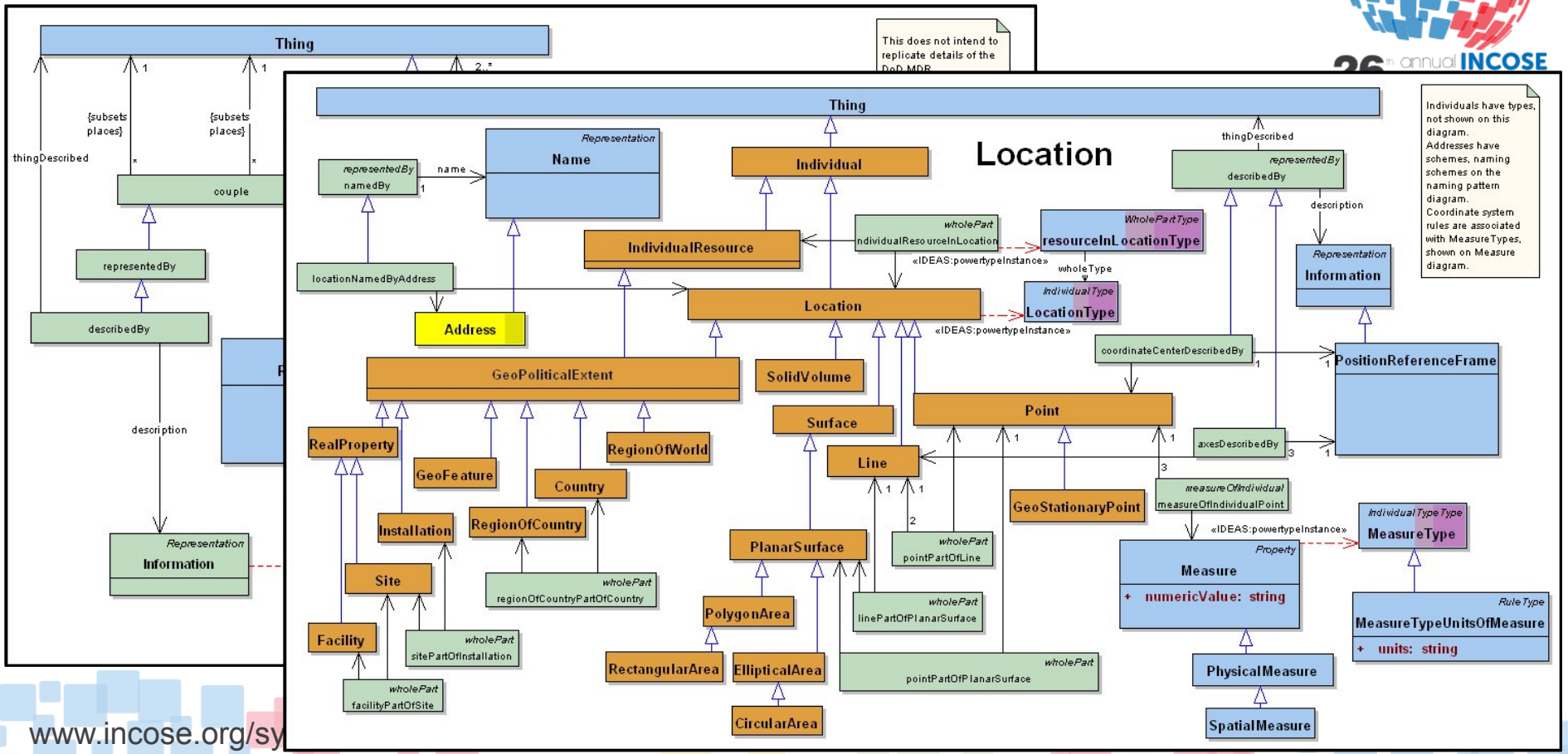
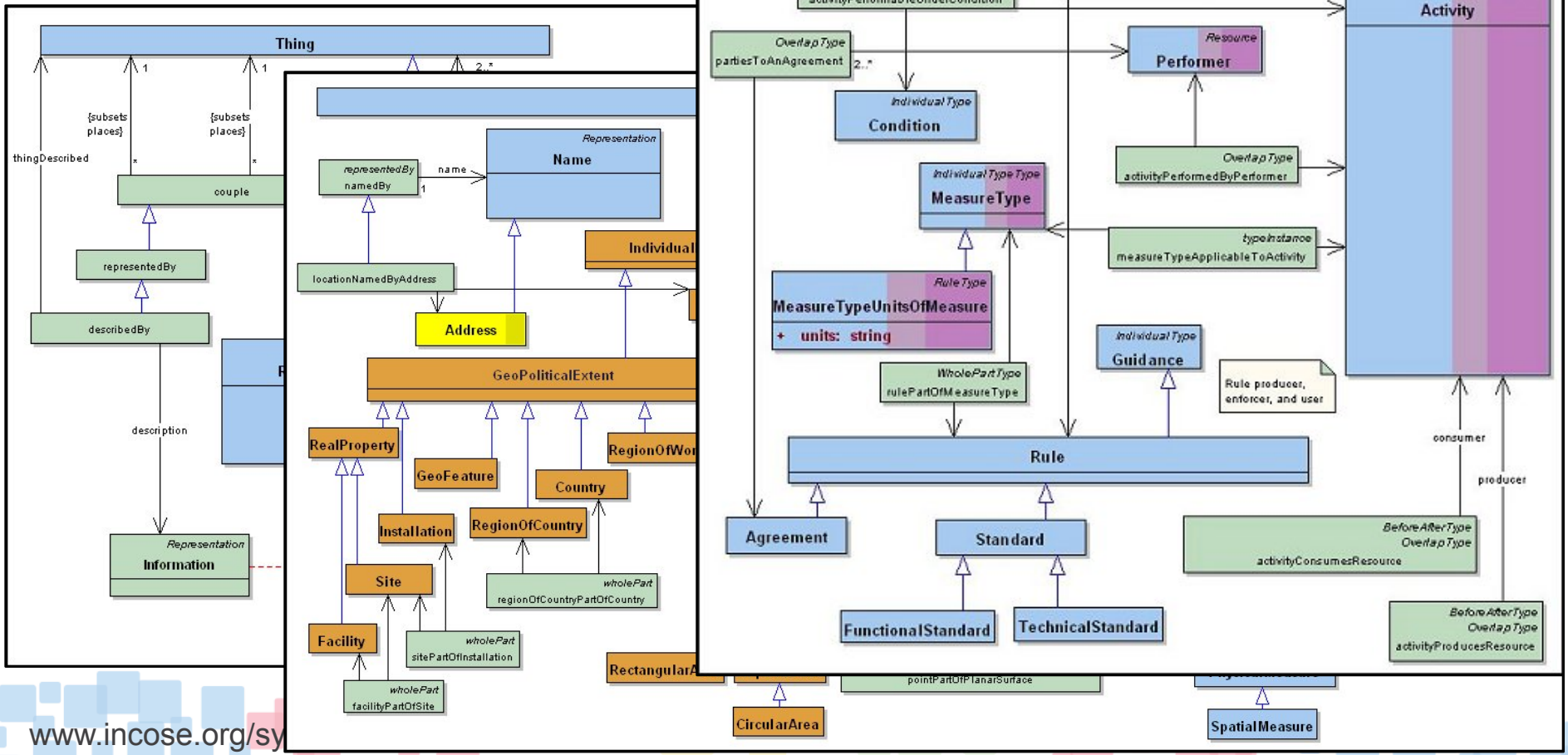
MBSE


Information and Data
This does not intend to replicate details of the DoD MDR.
Thing
1
1
2..*
places
{subsets places}
{subsets places}
tuple
thingDescribed
couple
associationOfInformation
associateOne
associateTwo
relationship
InformationType
representedBy
describedBy
IndividualType
Resource
BeforeAfterType
OverlapType
activityConsumesResource
consumer
IndividualType
Activity
description
BeforeAfterType
OverlapType
activityProducesResource
producer
superSubtype
ruleConstrainsActivity
SignTypeType
RepresentationType
Representation
Information
«IDEAS:powertypeInstance»
Guidance
Rule
DataType

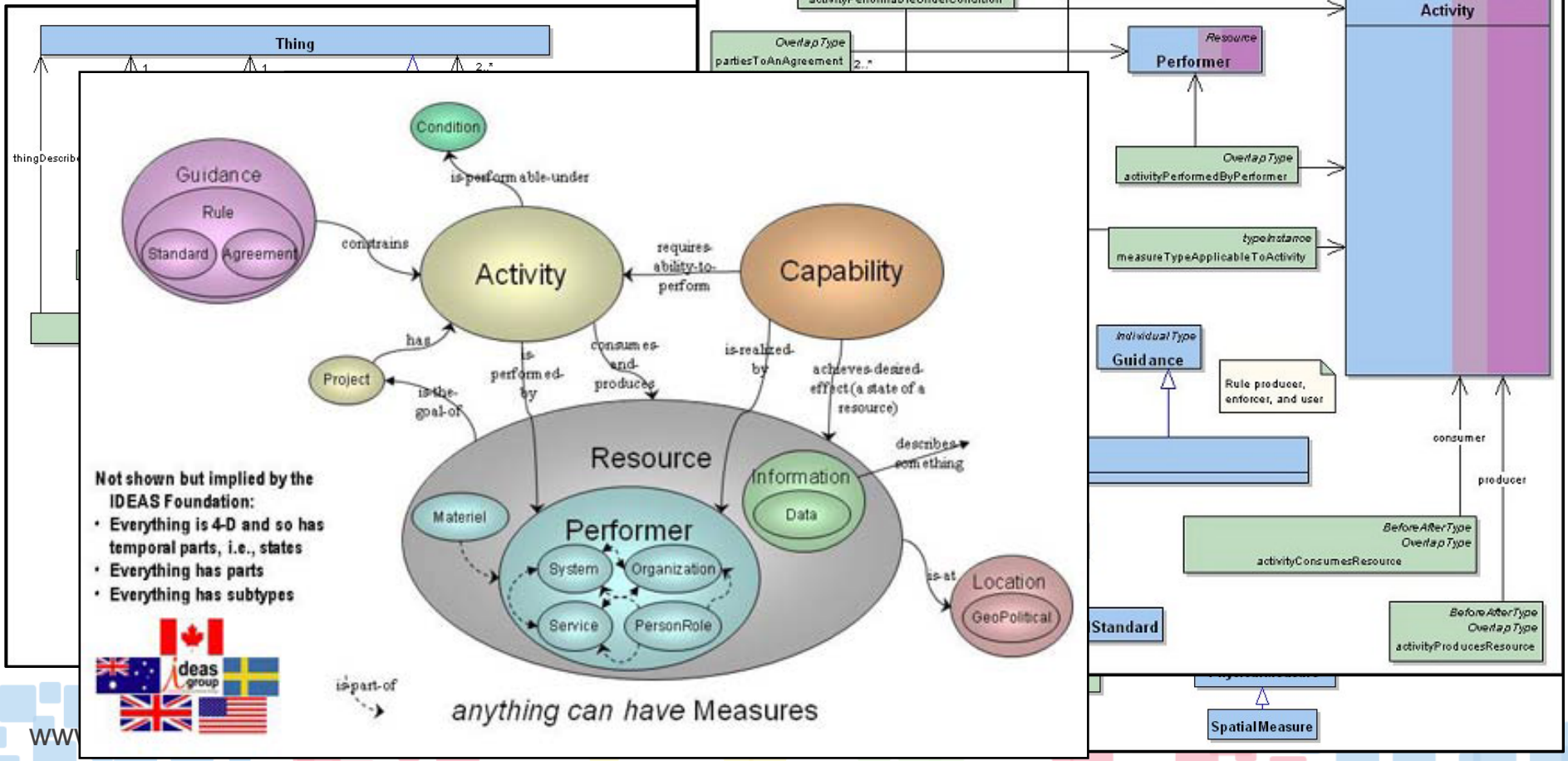
MBSE

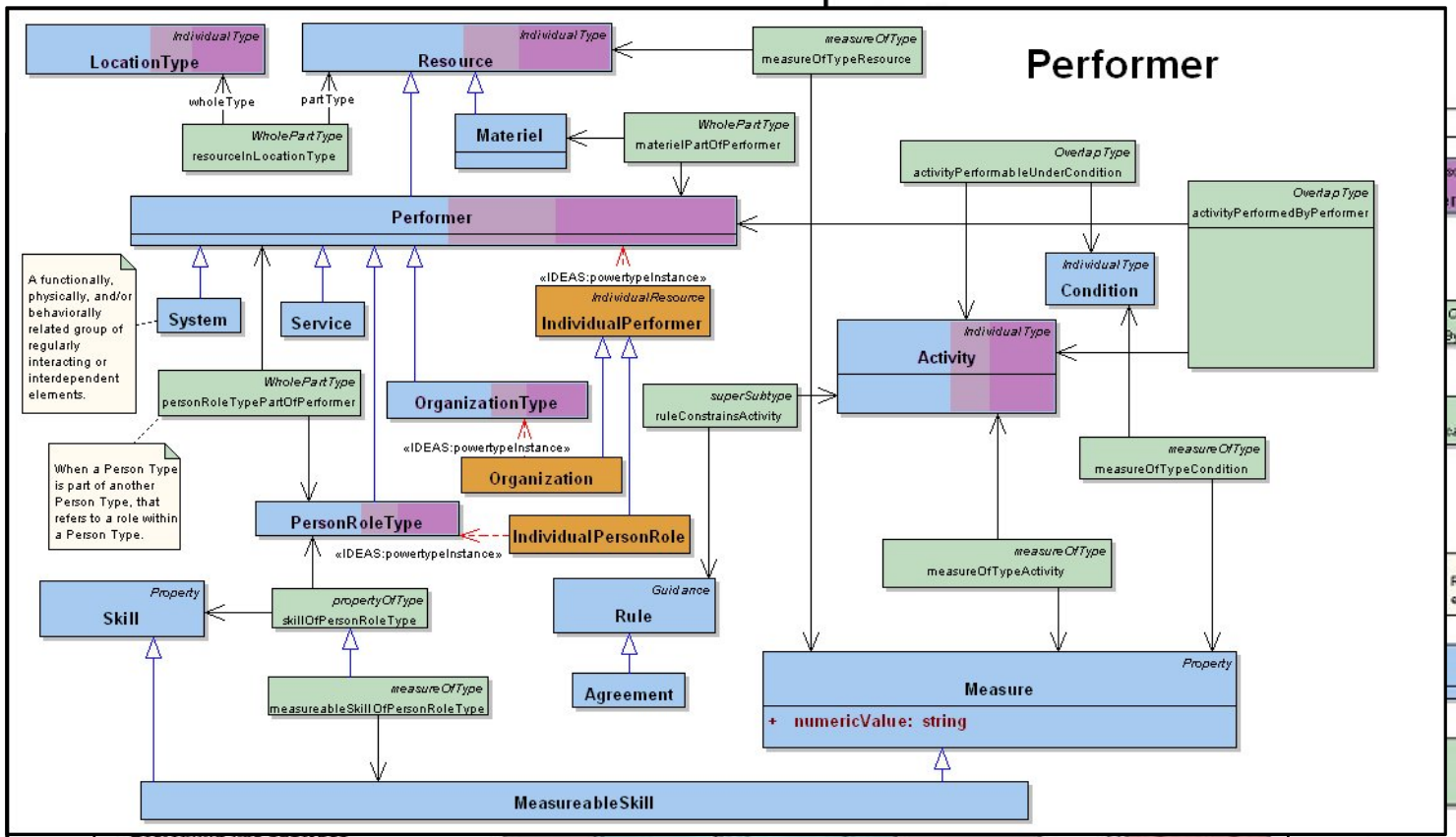

Thing
This does not intend to replicate details of the DoD MDR
Location
Individuals have types, not shown on this diagram.
Addresses have schemes, naming schemes on the naming pattern diagram.
Coordinate system rules are associated with MeasureTypes, shown on Measure diagram.
Representation
Name
Individual
IndividualResource
Address
Location
GeoPoliticalExtent
SolidVolume
Surface
Point
Line
PlanarSurface
PolygonArea
RectangularArea
EllipticalArea
CircularArea
RealProperty
GeoFeature
Country
RegionOfWorld
Installation
RegionOfCountry
Site
Facility
GeoStationaryPoint
PositionReferenceFrame
Representation
Information
IndividualType
LocationType
WholePartType
resourceInLocationType
MeasureType
Property
Measure
+ numericValue: string
PhysicalMeasure
SpatialMeasure
RuleType
MeasureTypeUnitsOfMeasure
+ units: string
representedBy
namedBy
name
thingDescribed
describedBy
description
coordinateCenterDescribedBy
axesDescribedBy
locationNamedByAddress
«IDEAS:powertypeInstance»
wholeType
wholePart
pointPartOfLine
linePartOfPlanarSurface
pointPartOfPlanarSurface
regionOfCountryPartOfCountry
sitePartOfInstallation
facilityPartOfSite
measureOfIndividual
measureOfIndividualPoint
couple
{subsets places}

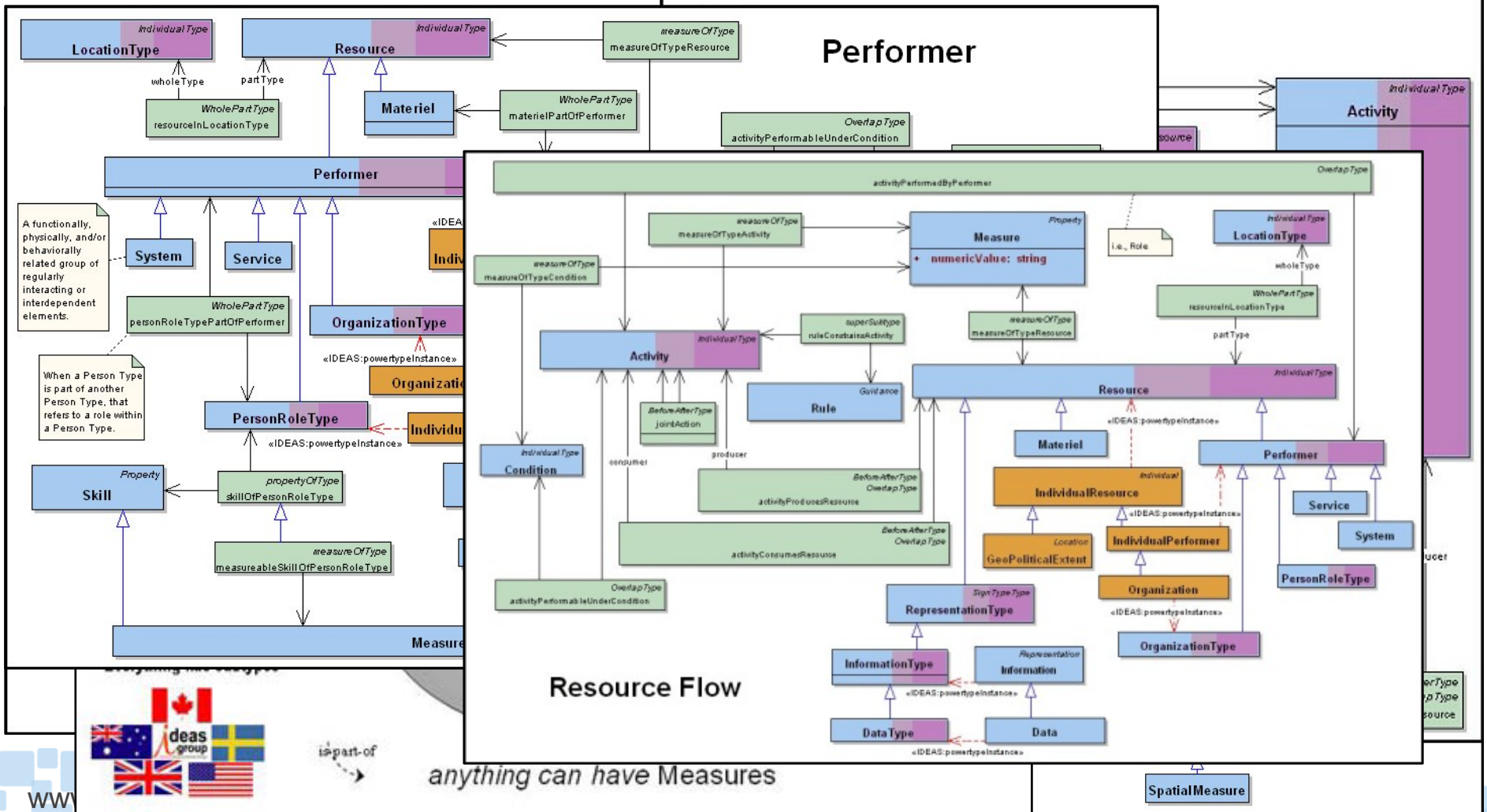
MBS


Rules
Thing
couple
representedBy
describedBy
description
Information
thingDescribed
{subsets places}
Representation
Name
representedBy
namedBy
name
locationNamedByAddress
Address
GeoPoliticalExtent
RealProperty
GeoFeature
Country
Installation
RegionOfCountry
Site
Facility
wholePart
regionOfCountryPartOfCountry
wholePart
sitePartOfInstallation
wholePart
facilityPartOfSite
CircularArea
pointPartOfPlanarSurface
SpatialMeasure
OverlapType
activityPerformableUnderCondition
partiesToAnAgreement
Condition
Performer
Resource
IndividualType
MeasureType
IndividualTypeType
RuleType
MeasureTypeUnitsOfMeasure
+ units: string
WholePartType
rulePartOfMeasureType
Guidance
Rule producer, enforcer, and user
Rule
Agreement
Standard
FunctionalStandard
TechnicalStandard
superSubtype
ruleConstrainsActivity
Activity
OverlapType
activityPerformedByPerformer
typeInstance
measureTypeApplicableToActivity
consumer
producer
BeforeAfterType
OverlapType
activityConsumesResource
activityProducesResource

MBS


Rules
Thing
OverlapType
activityPerformableUnderCondition
OverlapType
partiesToAnAgreement
2..*
superSubtype
ruleConstrainsActivity
Individual Type
Activity
Resource
Performer
OverlapType
activityPerformedByPerformer
typeInstance
measureTypeApplicableToActivity
Individual Type
Guidance
Rule producer, enforcer, and user
consumer
producer
BeforeAfterType
OverlapType
activityConsumesResource
BeforeAfterType
OverlapType
activityProducesResource
Standard
SpatialMeasure
Condition
is-performable-under
Guidance
Rule
Standard
Agreement
constrains
Activity
requires-ability-to-perform
Capability
has
Project
is-the-goal-of
is-performed-by
consumes-and-produces
is-realized-by
achieves-desired-effect (a state of a resource)
describes-something
Resource
Materiel
Performer
System
Organization
Service
PersonRole
Information
Data
is-at
Location
GeoPolitical
Not shown but implied by the IDEAS Foundation:
• Everything is 4-D and so has temporal parts, i.e., states
• Everything has parts
• Everything has subtypes
ideas group
is-part-of
anything can have Measures


Performer
LocationType
Resource
measureOfTypeResource
wholeType
partType
WholePartType
resourceInLocationType
Materiel
WholePartType
materielPartOfPerformer
OverlapType
activityPerformableUnderCondition
OverlapType
activityPerformedByPerformer
Performer
A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements.
System
Service
«IDEAS:powertypeInstance»
IndividualResource
IndividualPerformer
IndividualType
Condition
IndividualType
Activity
WholePartType
personRoleTypePartOfPerformer
OrganizationType
«IDEAS:powertypeInstance»
Organization
superSubtype
ruleConstrainsActivity
measureOfType
measureOfTypeCondition
When a Person Type is part of another Person Type, that refers to a role within a Person Type.
PersonRoleType
«IDEAS:powertypeInstance»
IndividualPersonRole
measureOfType
measureOfTypeActivity
Property
Skill
propertyOfType
skillOfPersonRoleType
Guidance
Rule
Property
Measure
+ numericValue: string
measureOfType
measureableSkillOfPersonRoleType
Agreement
MeasureableSkill
IndividualType
Activity
Rule producer, enforcer, and user
consumer
producer
BeforeAfterType
OverlapType
activityConsumesResource
BeforeAfterType
OverlapType
activityProducesResource
Service
PersonRole
GeoPolitical
Standard
is-part-of
anything can have Measures
SpatialMeasure


Performer
LocationType
Individual Type
Resource
measureOfType
measureOfTypeResource
wholeType
partType
WholePartType
resourceInLocationType
Materiel
WholePartType
materielPartOfPerformer
OverlapType
activityPerformableUnderCondition
Activity
Performer
A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements.
System
Service
WholePartType
personRoleTypePartOfPerformer
OrganizationType
«IDEAS:powertypeInstance»
When a Person Type is part of another Person Type, that refers to a role within a Person Type.
PersonRoleType
«IDEAS:powertypeInstance»
Property
Skill
propertyOfType
skillOfPersonRoleType
measureOfType
measureableSkillOfPersonRoleType
Measure
activityPerformedByPerformer
measureOfTypeActivity
Measure
+ numericValue: string
measureOfTypeCondition
i.e., Role
LocationType
wholeType
WholePartType
resourceInLocationType
partType
superSubtype
ruleConstrainsActivity
measureOfType
measureOfTypeResource
Activity
Rule
Guidance
Resource
BeforeAfterType
jointAction
«IDEAS:powertypeInstance»
Materiel
Performer
Condition
consumer
producer
BeforeAfterType
OverlapType
activityProducesResource
Individual
IndividualResource
«IDEAS:powertypeInstance»
Service
System
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activityConsumesResource
Location
GeoPoliticalExtent
IndividualPerformer
PersonRoleType
OverlapType
activityPerformableUnderCondition
SignTypeType
RepresentationType
Organization
«IDEAS:powertypeInstance»
OrganizationType
InformationType
Representation
Information
«IDEAS:powertypeInstance»
DataType
Data
«IDEAS:powertypeInstance»
Resource Flow
is-part-of
anything can have Measures
SpatialMeasure

Performer

LocationType

Resource

measureOfType

measureOfTypeResource

wholeType

partType

Activity

A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements.

When a Person Type is part of another Person Type, that refers to a role within a Person Type.

Skill

Property

Service

System

SpatialMeasure

anything can have Measures

Model-Based Systems Engineering

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- None (document-centric)
- Requirements Management Tool (RMT)
- **RMT and Diagrams**
- RMT and Diagrams with Analysis Capabilities

Simplify the Schema

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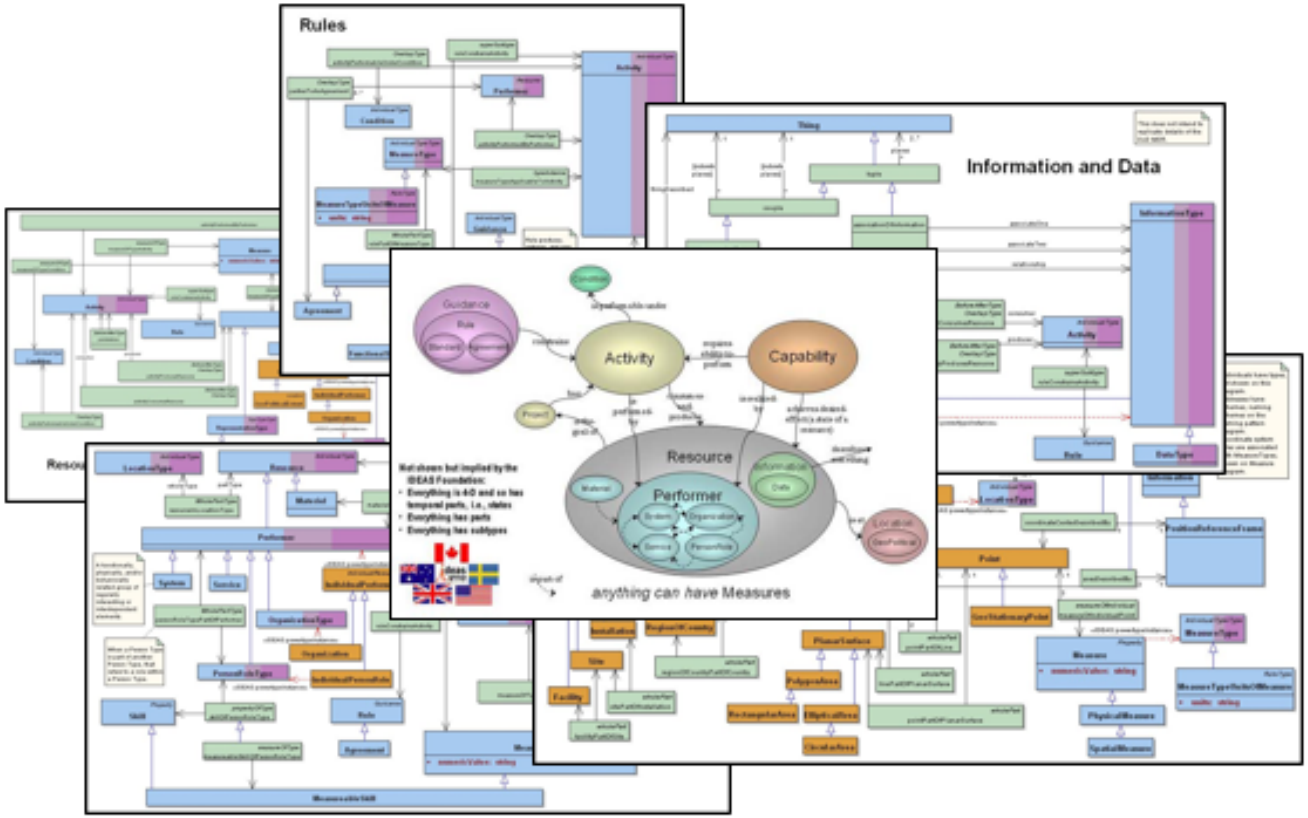
- Simplify to achieve promised results from MBSE for:
  - MBSE beginners
  - Small / medium projects
- Schema = structure / framework
  - What items are captured
  - What items trace to others
  - What attributes are stored with each item
  - What document artifacts are created

Simplify the Schema



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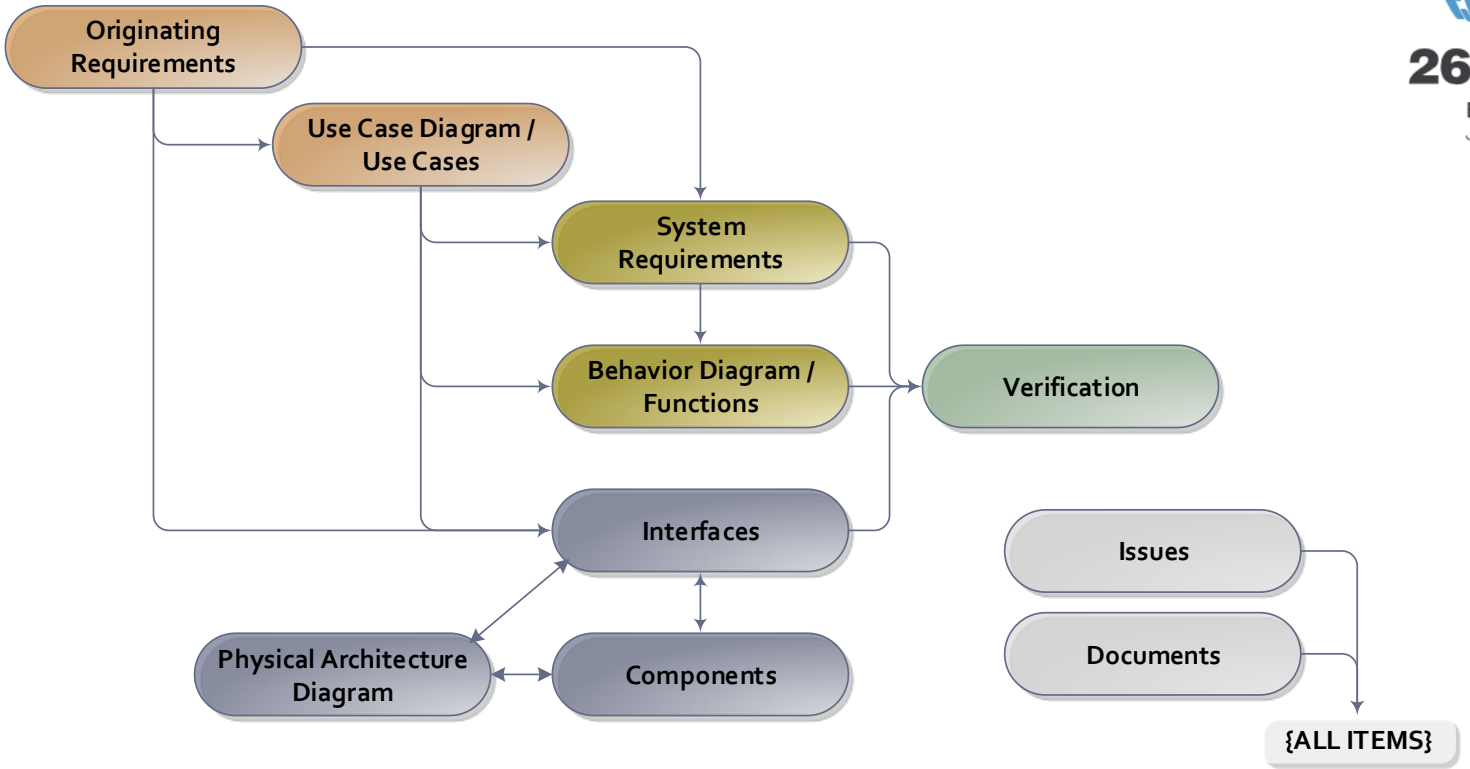
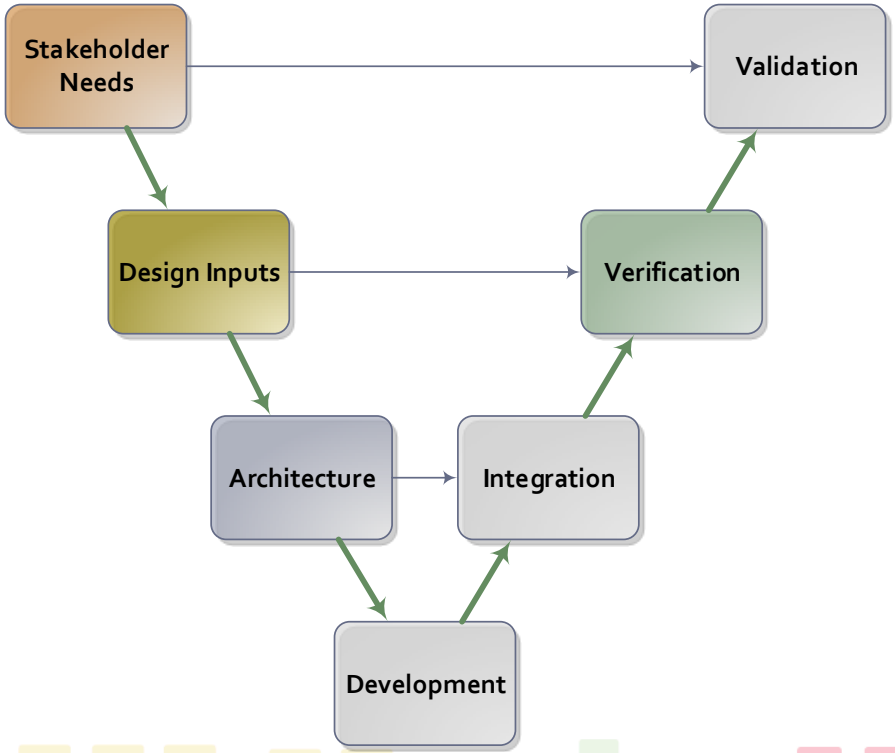
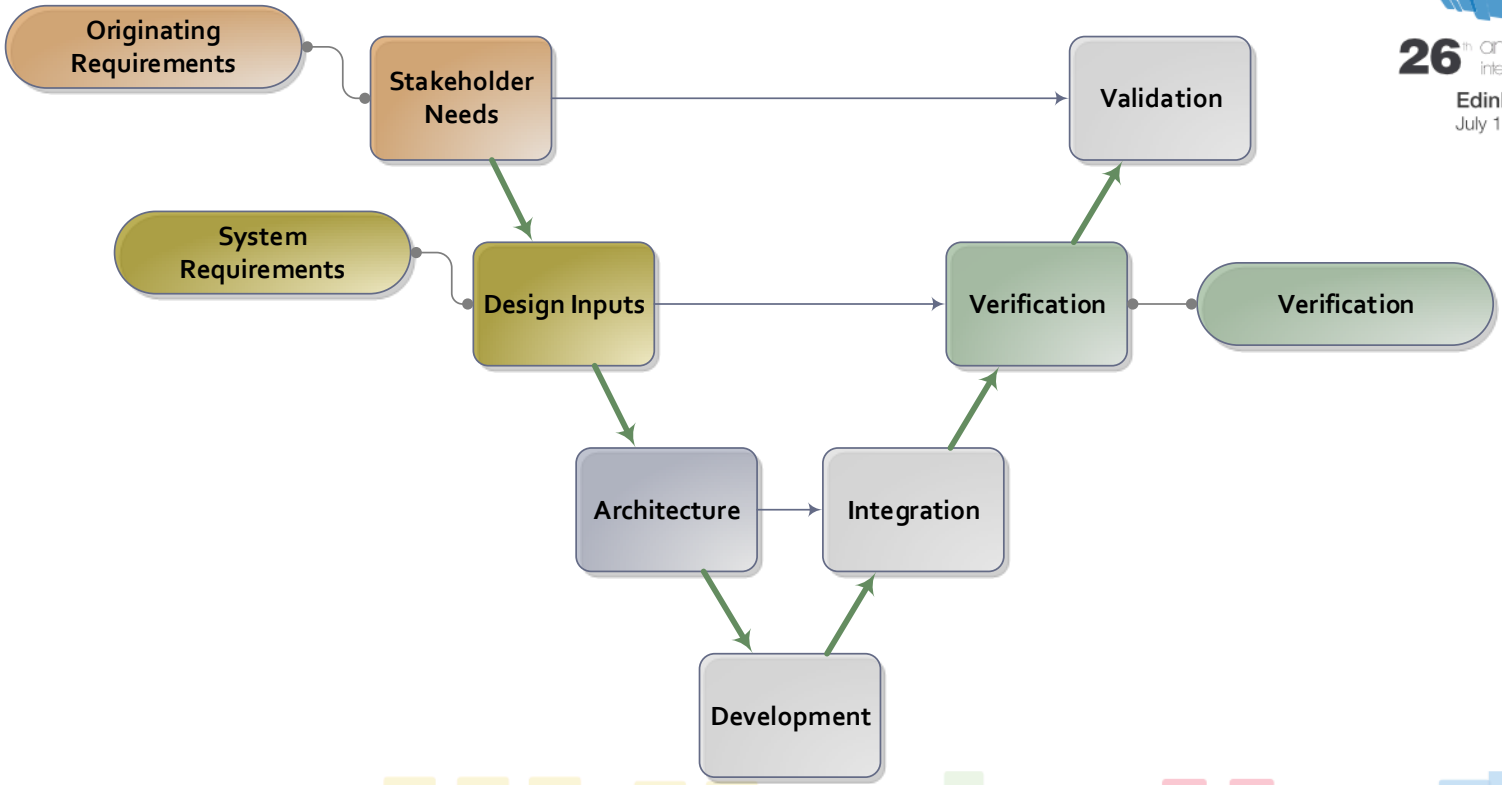
Simplify the Schema



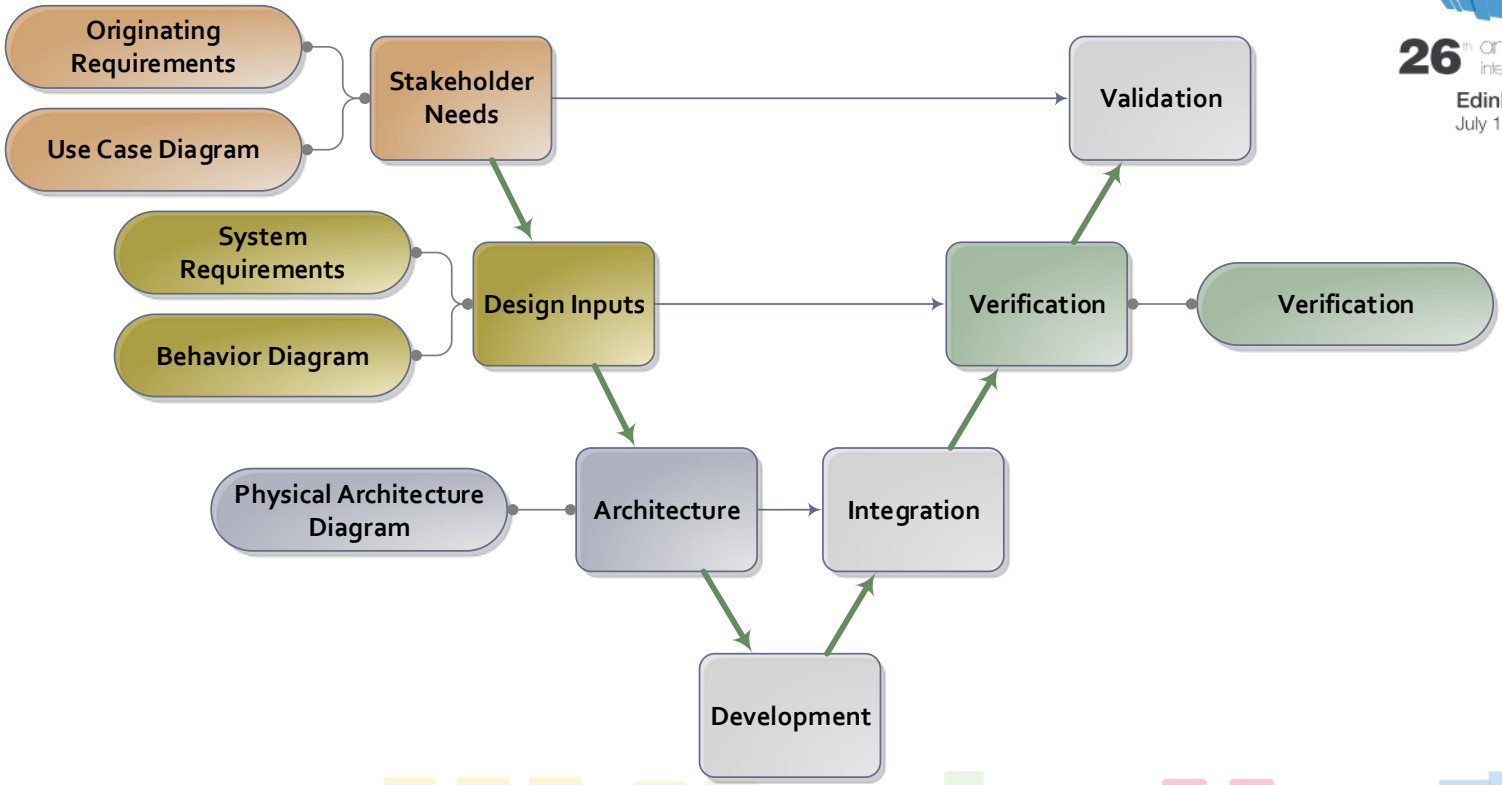
What Items are Captured?



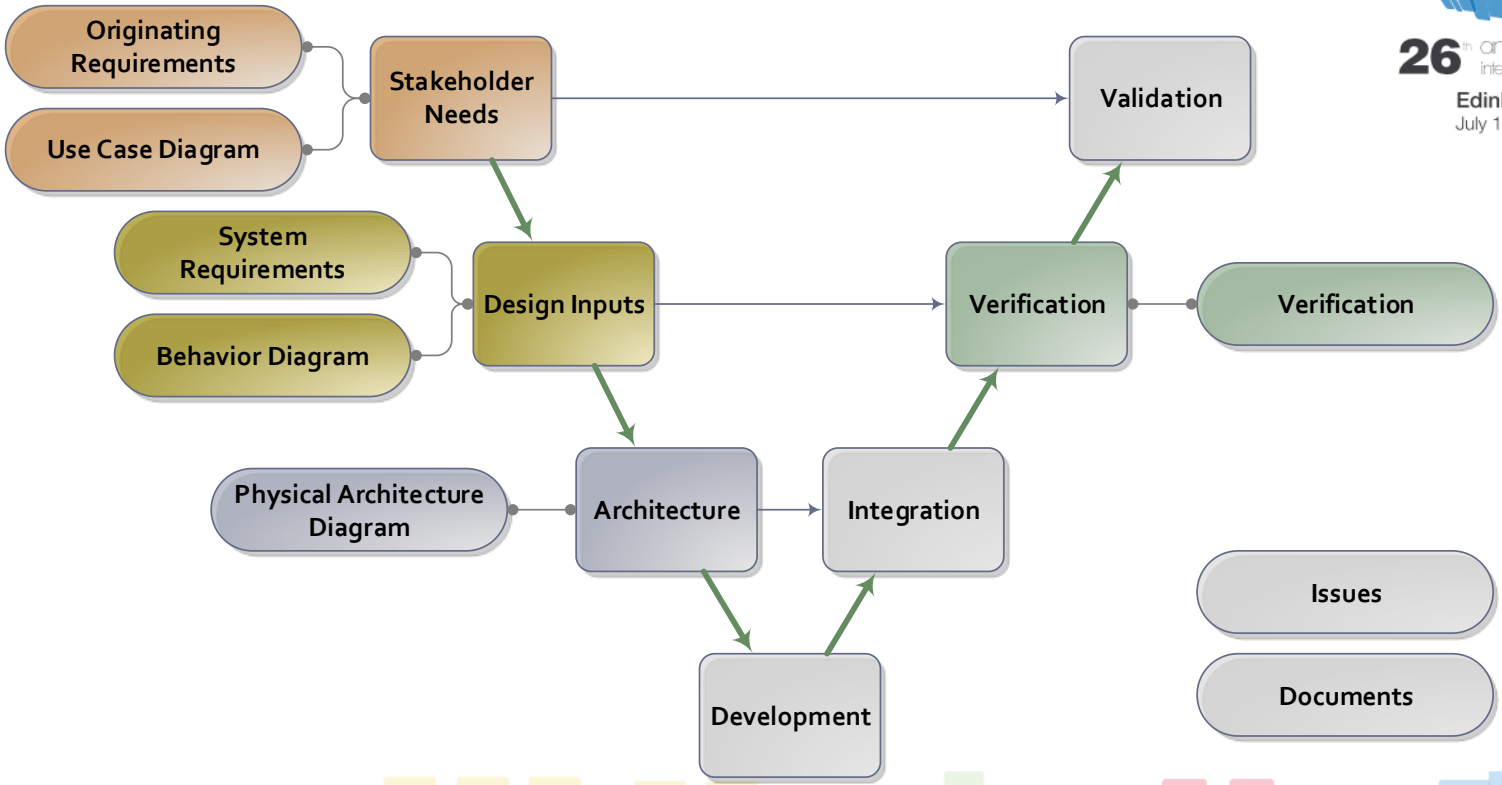
What Items are Captured?



What Items are Captured?



What Items are Captured?



Input Documents

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- Documented source for items
- Allows insight into why and when items were created or changed

DOC-1 | Medical devices software – Software life cycle processes

Doc Number: IEC 62304 Doc Rev: 2006
Doc Type: Regulatory Standard

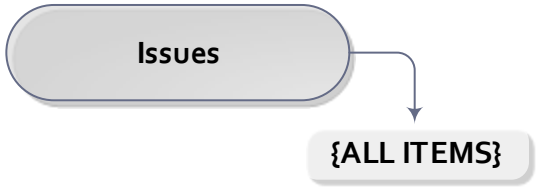
DOC-2 | Charge LED color

Doc Number: N/A Doc Rev: N/A
Doc Type: Email

Description: Blinking yellow LED selected for charging

Issues

- Capture issues and questions
- Maintain a history of key decisions
- Link issues to affected items to show the impact of a decision



INT-1 | Power Interface **Status: Initial**

The device connects to a power supply via a connector for charging.

ISS-1 | Power Interface **Status: Assigned**

Impact: Medium
Owner: Electrical
Date Raised: 1 Oct 2015
Target Date: 1 Nov 2015

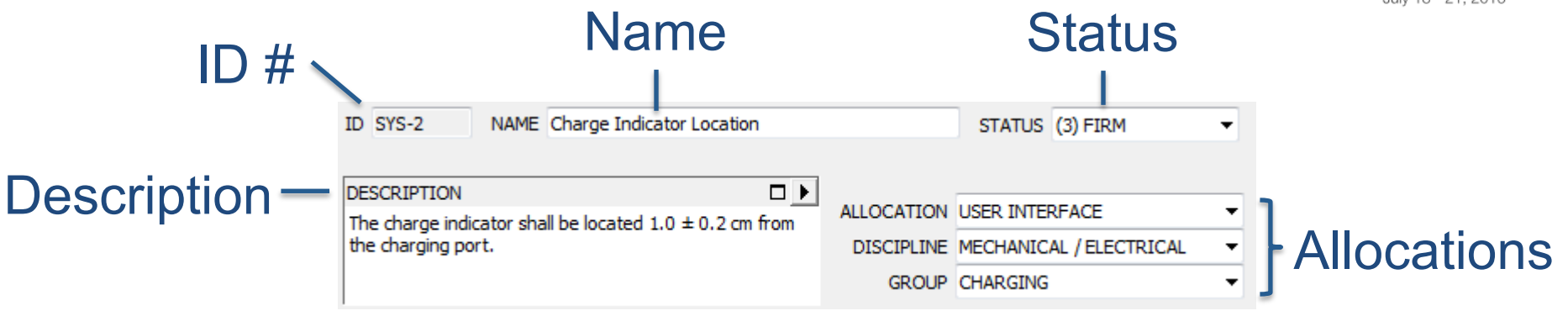
Need to define the power interface for charging.

Alternatives:

- USB
- EIAJ

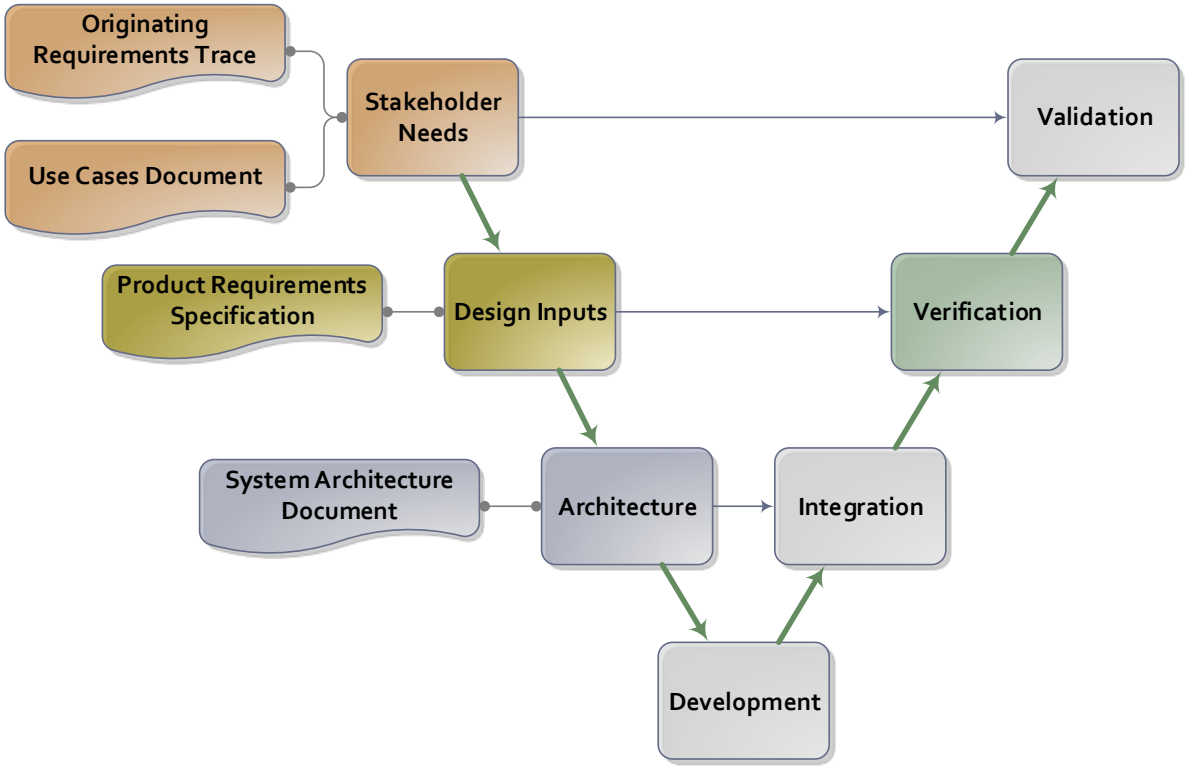
Anatomy of an Item

- Core set of attributes used on nearly all items

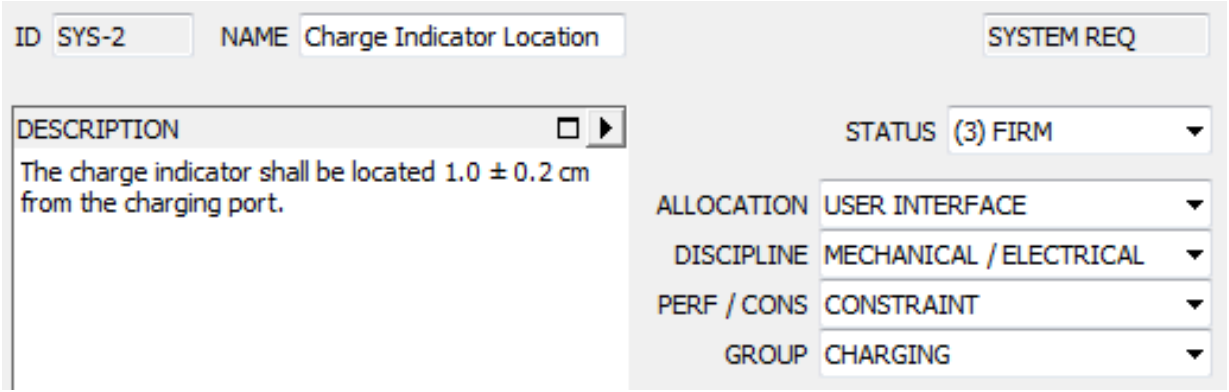


- Additional attributes added as necessary

Output Documents



Output Documents

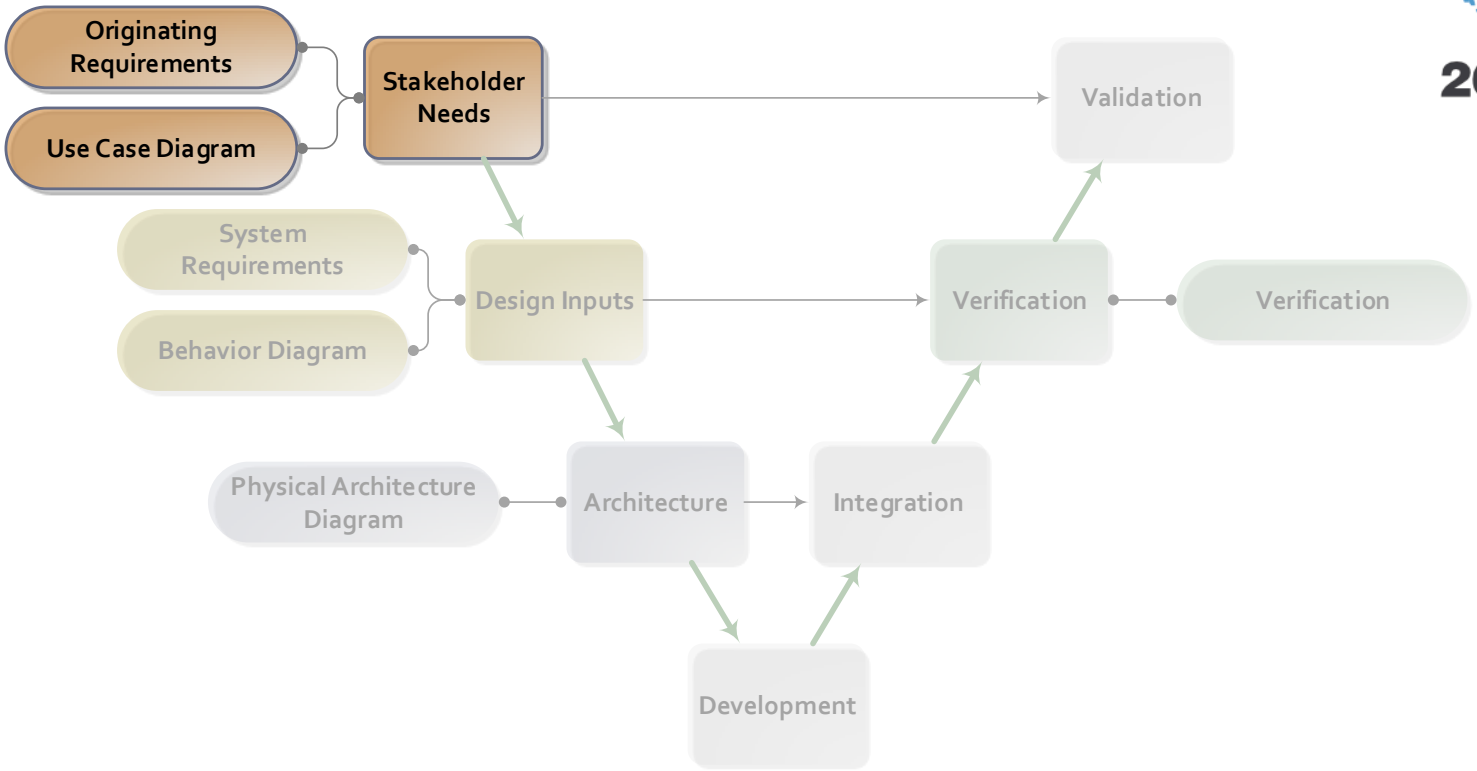


SYS-2 | Charge Indicator Location **Status: Firm**

Allocation: User Interface Discipline: Mechanical / Electrical
Group: Charging

The charge indicator shall be located 1.0 ± 0.2 cm from the charging port.

Stakeholder Needs



Goal 1: Reconcile Project Inputs

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1. Capture

Documents

Originating Requirements

2. Trace
3. Reconcile

Use Cases

Interfaces

System Requirements

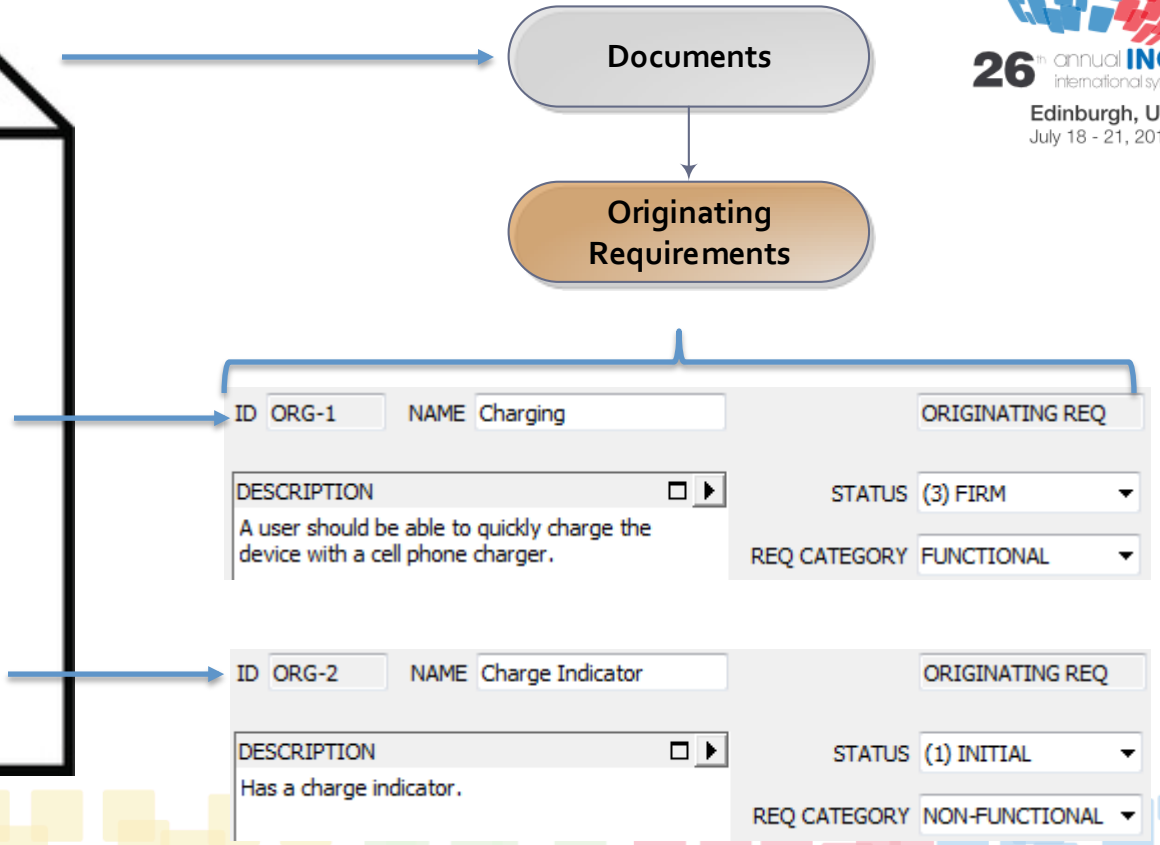
Originating Requirements Trace

4. Output document

Capture

RFQ

- A user should be able to quickly charge the device with a cell phone charger.
- Has a charge indicator.



Trace, Reconcile, and Output

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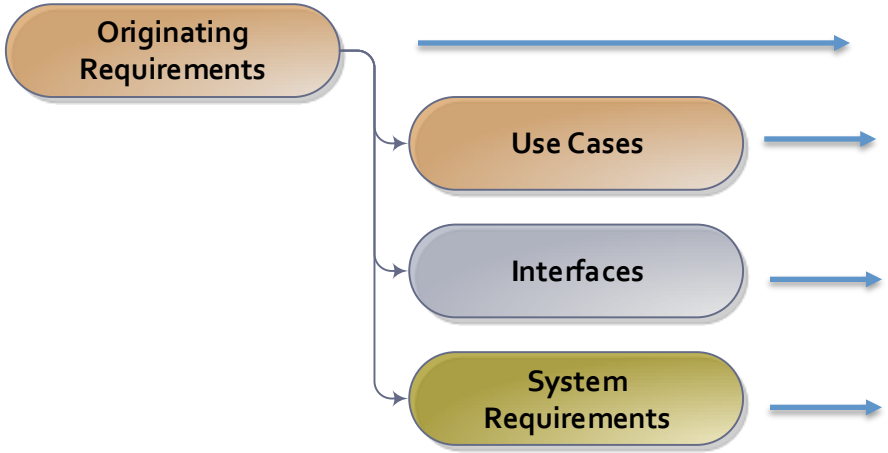


ORG-1 | Charging **Status: Firm**

A user should be able to quickly charge the device with a cell phone charger.

UCD-1 | Charging **Status: Initial**

The device battery is re-charged.

INT-1 | Power Interface **Status: Initial**

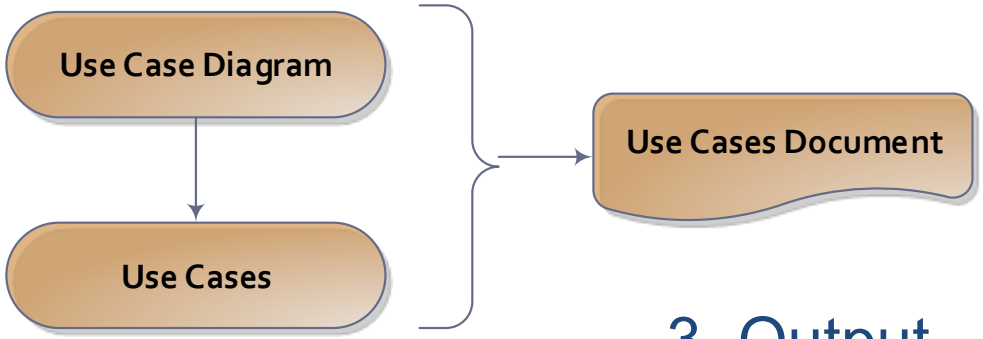
The device connects to a power supply via a connector for charging. This is likely a coaxial barrel connector.

SYS-1 | Charge Duration **Status: Proposed**

A battery with <5% capacity shall charge to >95% capacity in <5 hours.

Goal 2: Uncover Missing High-level Needs

1. Consider overlooked use cases

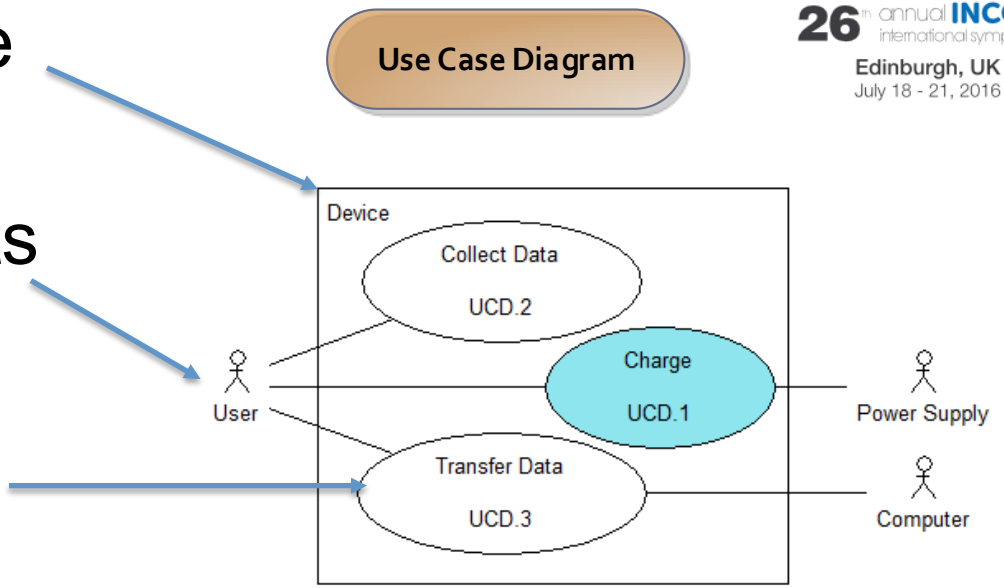


2. Add critical details

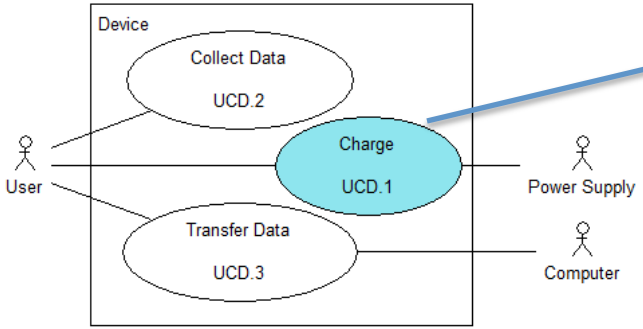
3. Output document

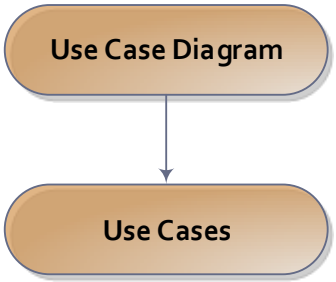
Consider Overlooked Use Cases

- What is in/out of the system?
- Who (what) interacts with the system?
- What are those interactions?



Add Details and Output





UCD.1 | Charge **Status: Proposed**

The device battery is re-charged.

Pre-conditions:

- Device has a partially depleted battery

Main event flow:

- User connects device to the charger
- The device's charge indicator blinks yellow to indicate charging
- The device charges
- The device's charge indicator turns green when charge is completed
- The user disconnects the device from the charger

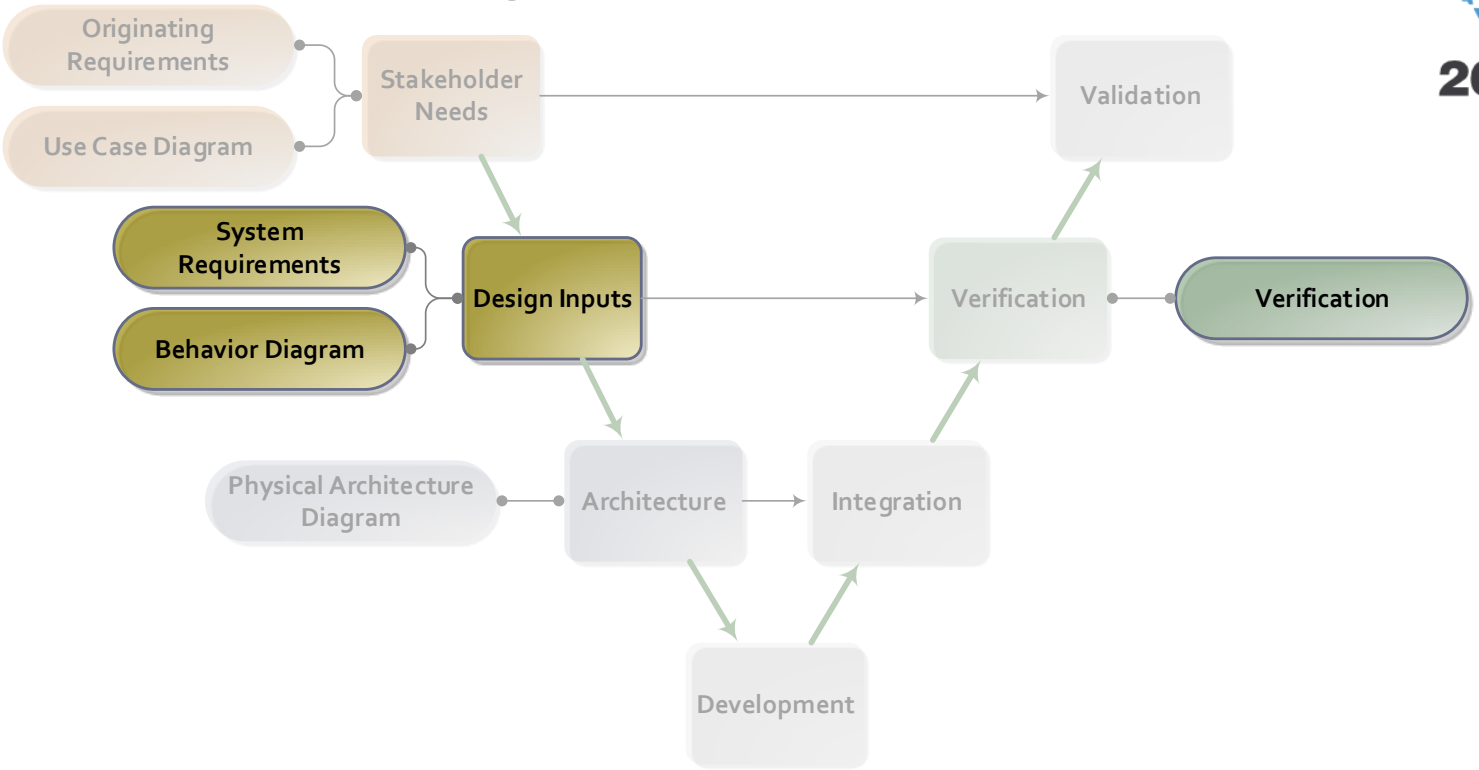
Post conditions:

- Device has a charged battery
- The charge indicator is green

Alternate flows:

- The user disconnects the device from the charger before charging is complete
- The charge indicator is yellow or red to indicate the battery charge level

Design Inputs



Goal: Provide Inputs to Architect the System

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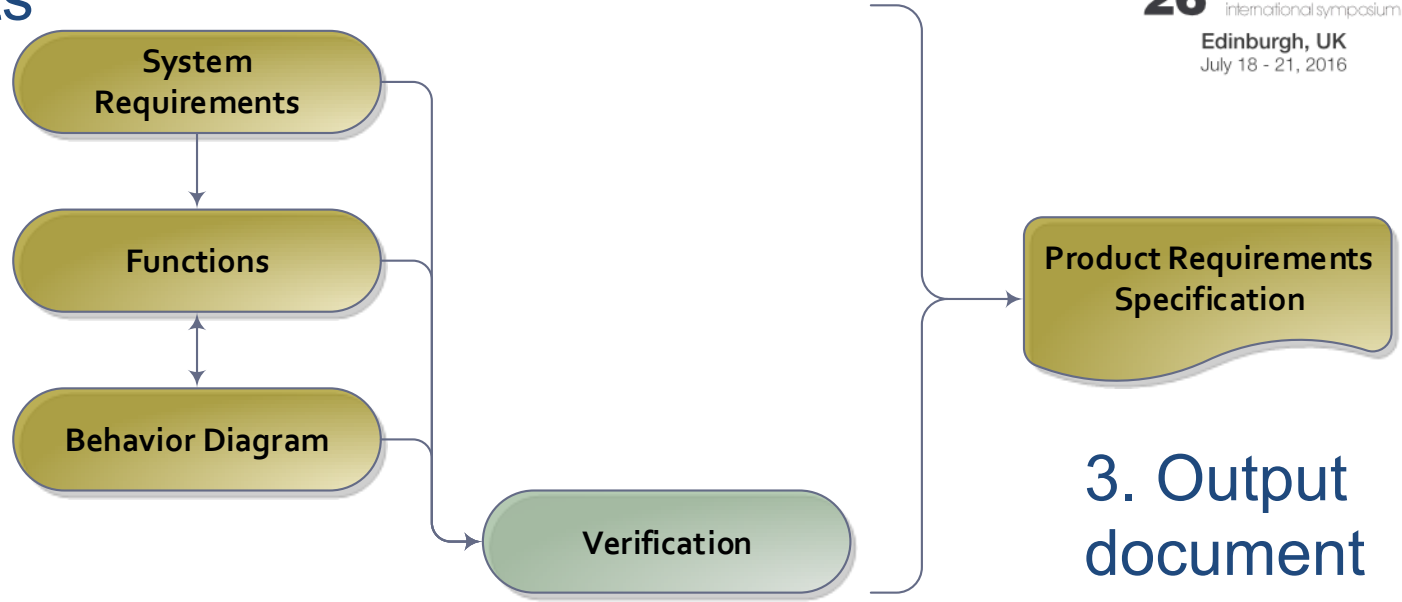
1. Requirements

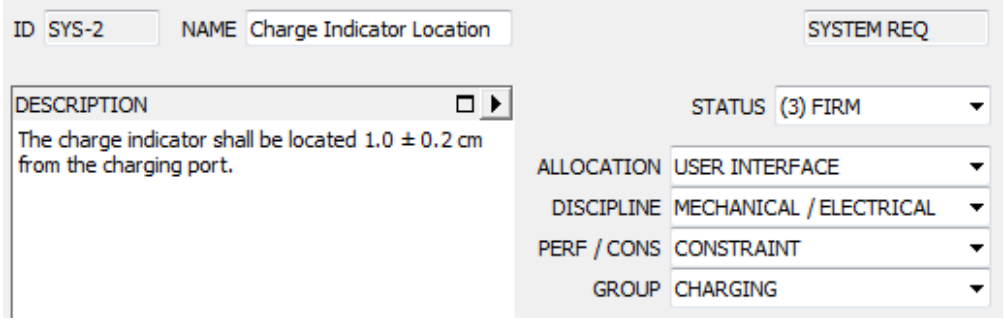


2. Plan verification

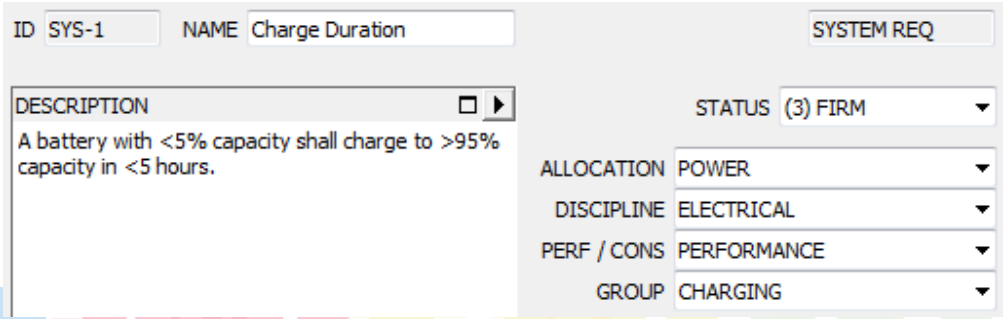
3. Output document

System Requirements

- Constraint – What the system ***is / has***



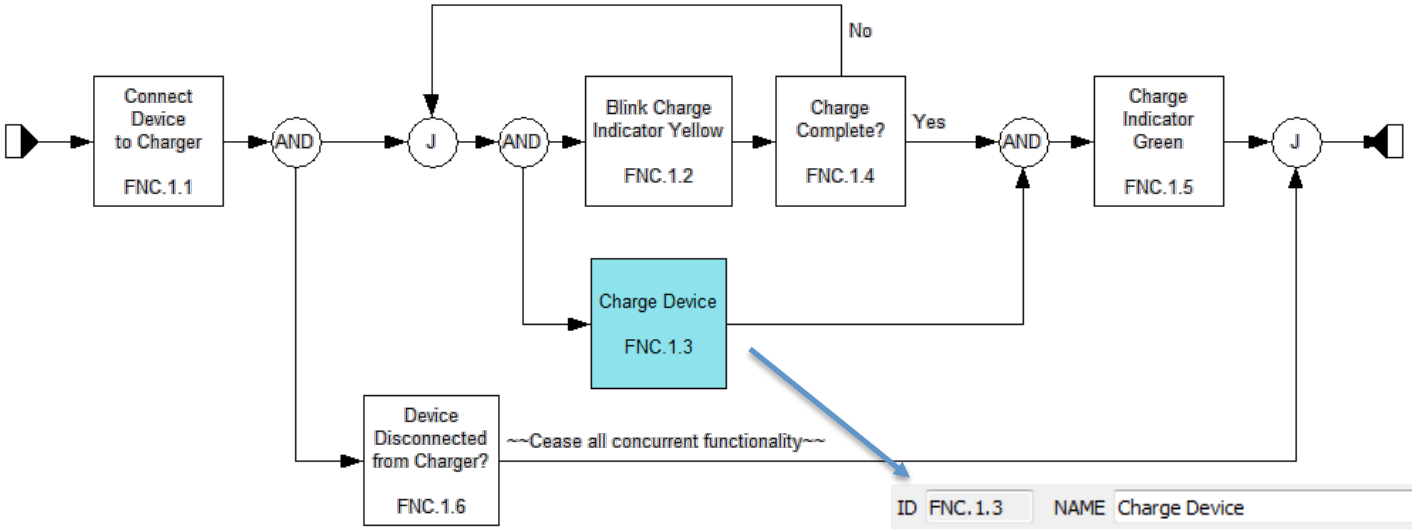
- Performance – What the system ***does***

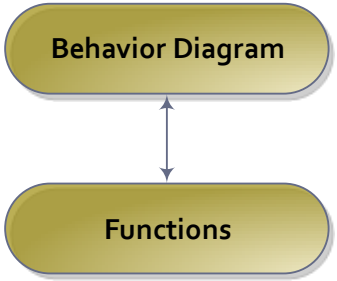


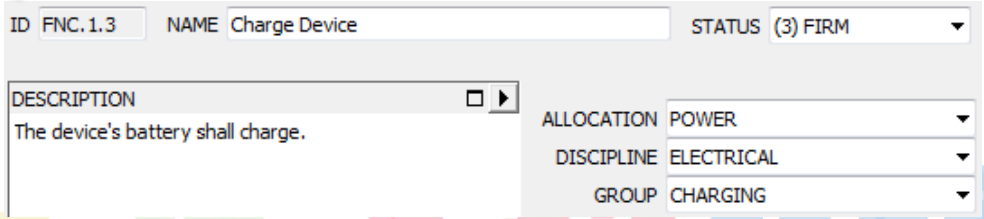
System Requirements

Behavior Diagrams

- Show the time dependency and decision dependence of functions







Keep Diagrams Simple

- ~5-9 items
- One diagram = one page
- Don’t do the engineer’s job for them

Performance Requirements

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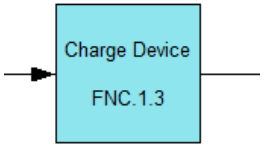
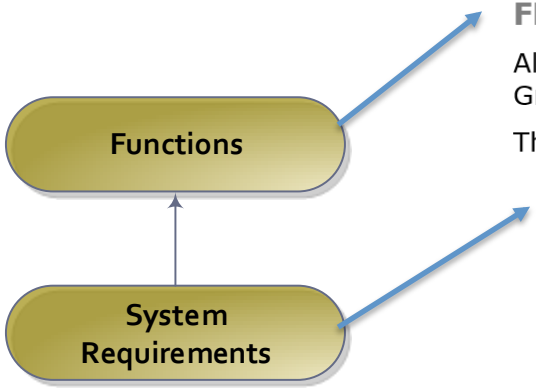
- Link performance requirements to functions
- Context!





FNC.1.3 | Charge Device — **Status: Firm**

Allocation: Power — Discipline: Electrical
Group: Charging

The device's battery shall charge.

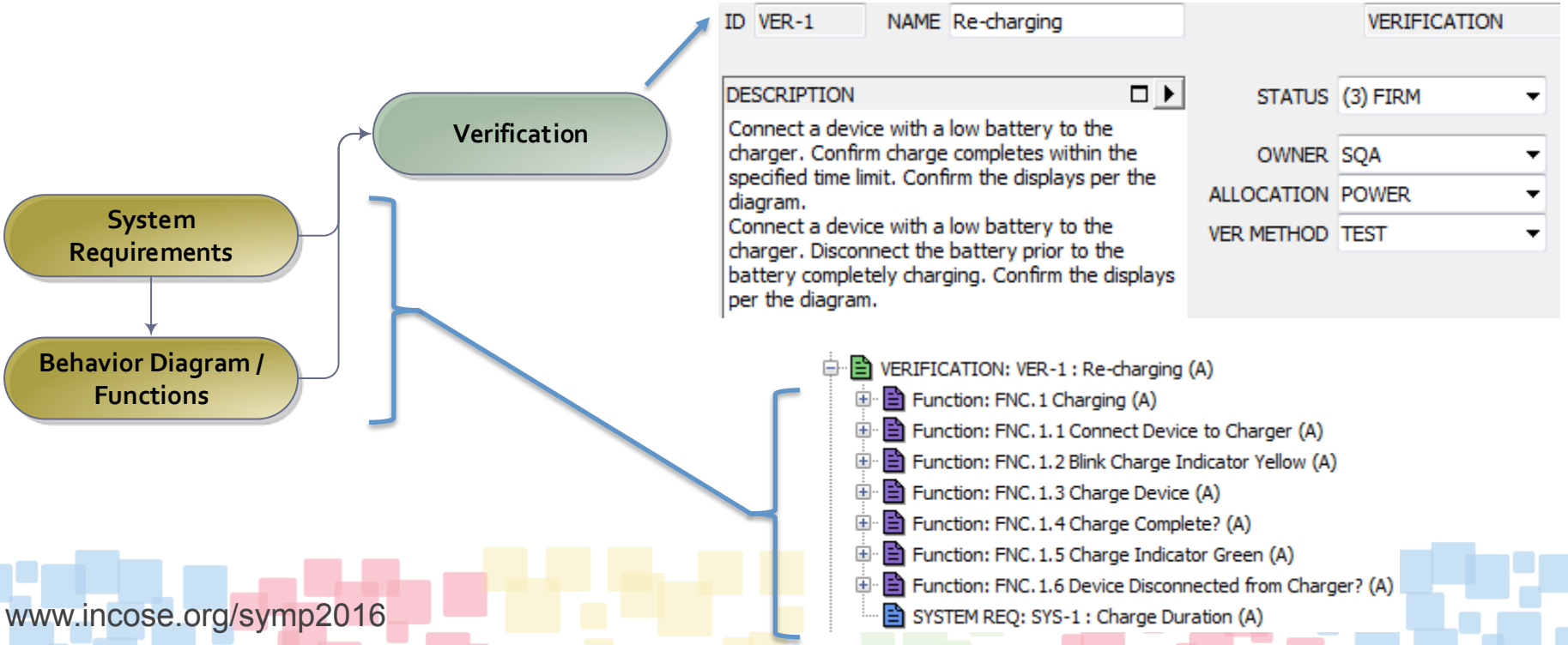
SYS-1 | Charge Duration — **Status: Firm**

Allocation: Power — Discipline: Electrical
Group: Charging

A battery with <5% capacity shall charge to >95% capacity in <5 hours.

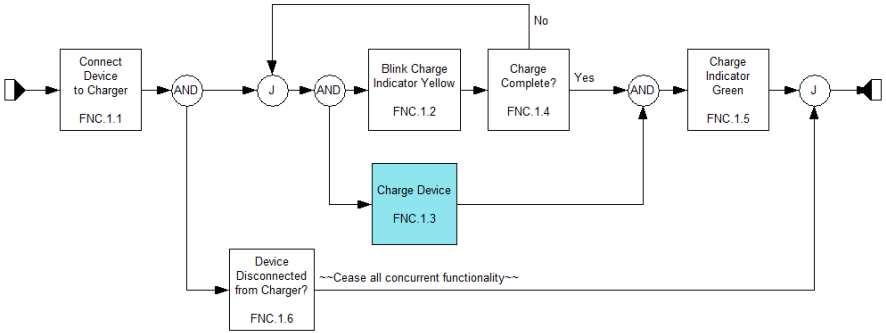
Plan Verification

- Alignment on method and owner



Output

- Functional Spec.
- Constraint Spec.
- Verification Plan



FNC.1.3 | Charge Device **Status: Firm**

Allocation: Power
Group: Charging

Discipline: Electrical

The device's battery shall charge.

SYS-1 | Charge Duration **Status: Firm**

Allocation: Power
Group: Charging

Discipline: Electrical

A battery with <5% capacity shall charge to >95% capacity in <5 hours.

Output

- Functional Spec.
- Constraint Spec.
- Verification Plan

SYS-2 | Charge Indicator Location **Status: Firm**

Allocation: User Interface Discipline: Mechanical / Electrical
Group: Charging

The charge indicator shall be located 1.0 ± 0.2 cm from the charging port.

Output

- Functional Spec.
- Constraint Spec.
- Verification Plan

VER-1 | Re-charging **Status: Firm**

Method: Test
Owner: SQA
Allocation: Power

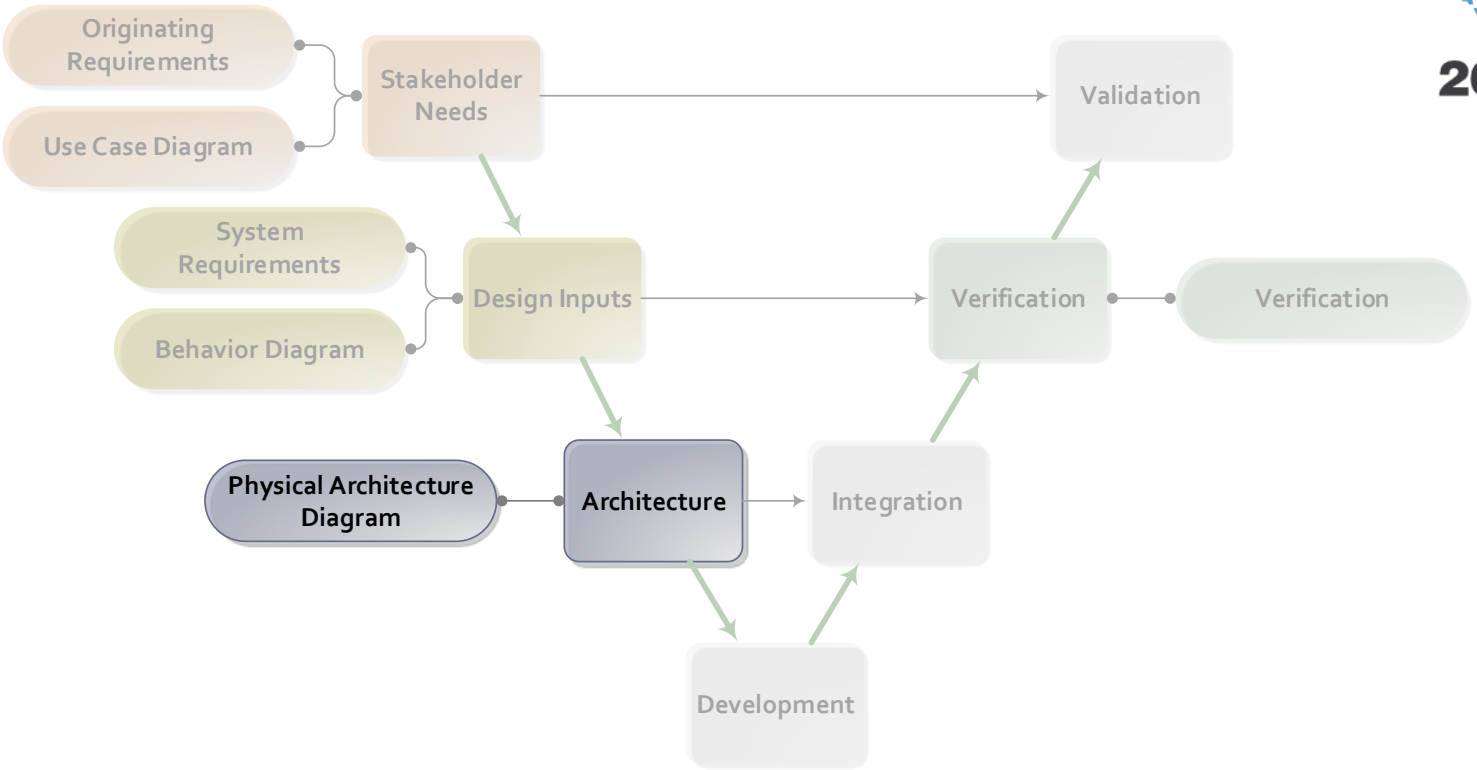
Connect a device with a low battery to the charger. Confirm charge completes within the specified time limit. Confirm the displays per the diagram.

Connect a device with a low battery to the charger. Disconnect the battery prior to the battery completely charging. Confirm the displays per the diagram.

Linked Requirements:

- SYS-1 | Charge Duration
- FNC.1 | Charging
- FNC.1.1 | Connect Device to Charger
- FNC.1.2 | Blink Charge Indicator Yellow
- FNC.1.3 | Charge Device
- FNC.1.4 | Charge Complete?
- FNC.1.5 | Charge Indicator Green
- FNC.1.6 | Device Disconnected from Charger?

Architecture



Goal: Select Architecture that Meets Requirements

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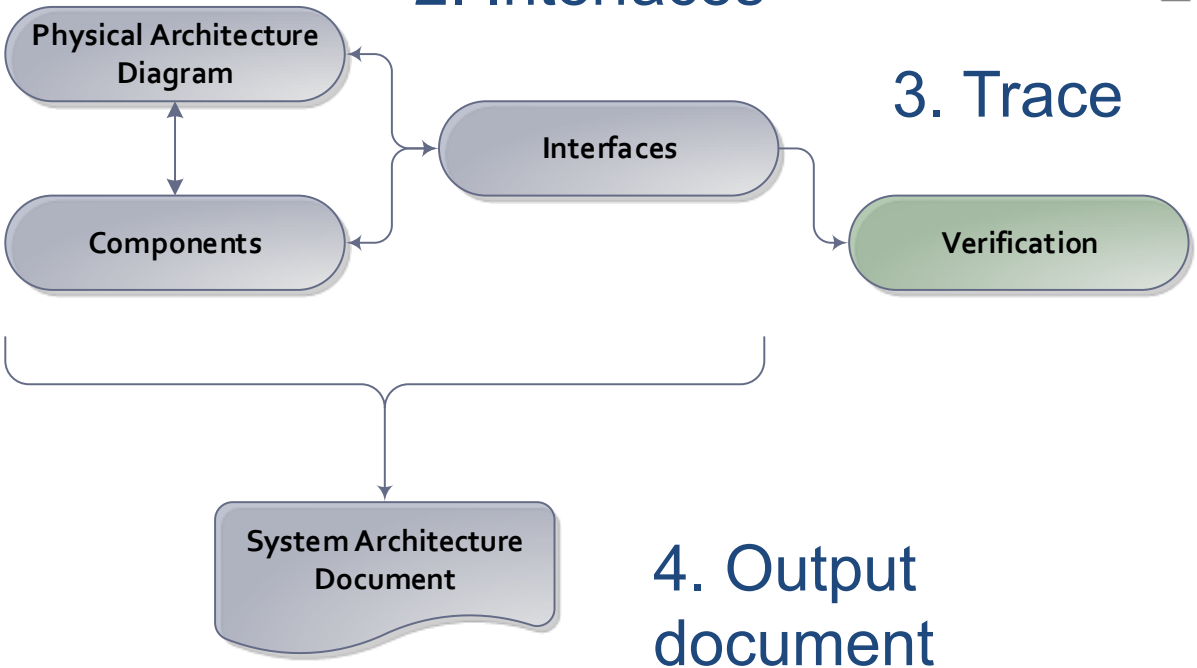
1. Architecture(s)

2. Interfaces

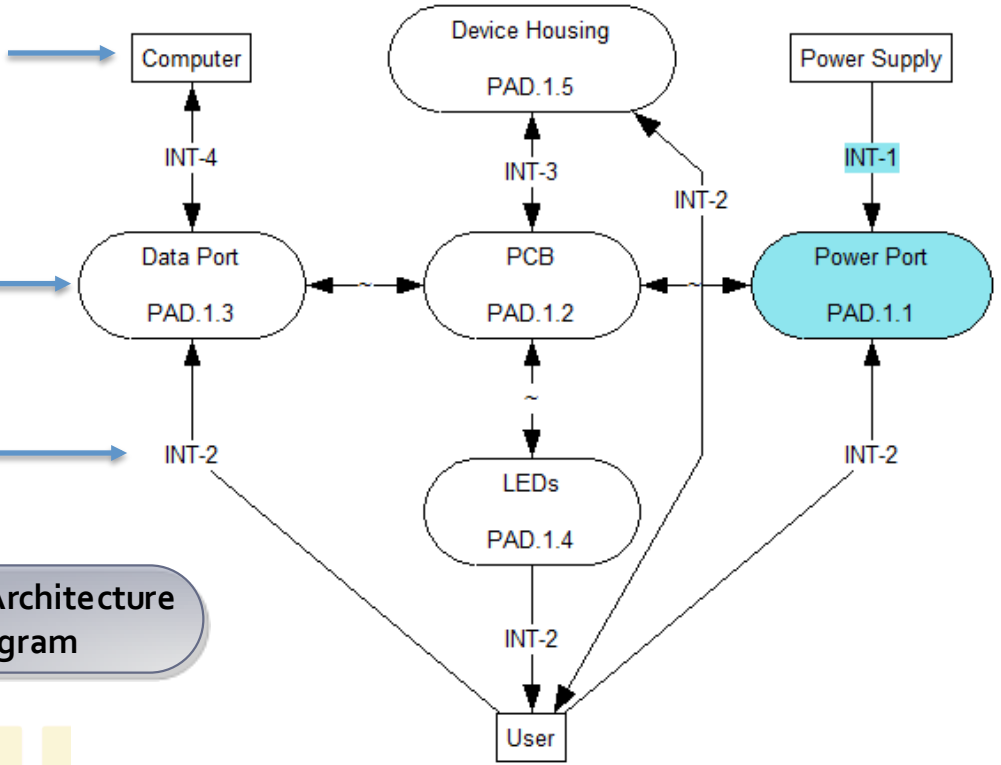


3. Trace

4. Output document

Architecture Diagram

- Who (what) interacts with the system?
- What comprises the system?
- How is everything connected?



Physical Architecture Diagram

Internal vs External Interfaces

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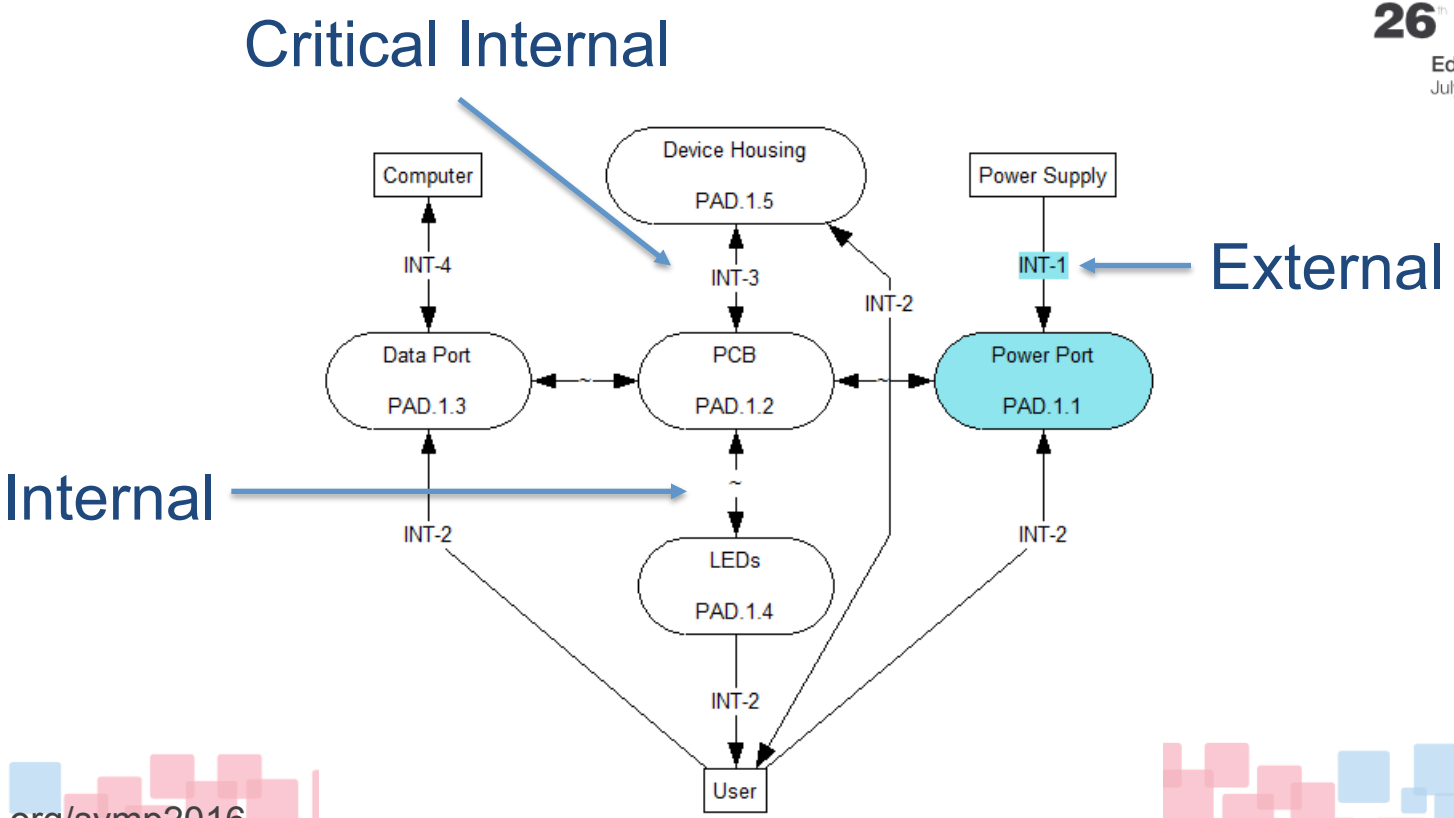
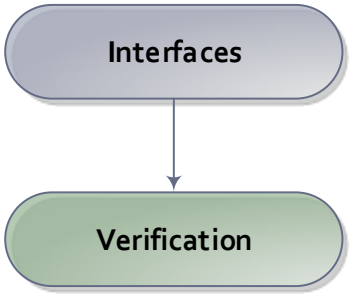


Interfaces and Trace

- Interfaces are requirements!



ID INT-1

NAME
Power Interface

Interface Data Defn

DESCRIPTION
The device connects to a power supply via a connector for charging.

STATUS (3) FIRM

EXT/INT EXTERNAL

MECHANICAL DESCRIPTION
- The power interface shall be an EIAJ-02 coaxial power connector.
- The power supply shall contain the plug, the device shall contain the jack.

ELECTRICAL DESCRIPTION
- The device shall receive 1A max, 5V ± 25mV via the power interface.

SOFTWARE DESCRIPTION
N/A

Output

Interfaces

INT-1 | Power Interface | External **Status: Firm**

The device connects to a power supply via a connector for charging.

Mechanical Description:

- The power interface shall be an EIAJ-02 coaxial power connector.
- The power supply shall contain the plug, the device shall contain the jack.

Electrical Description:

- The device shall receive 1A max, 5V ± 25mV via the power interface.

Software Description:

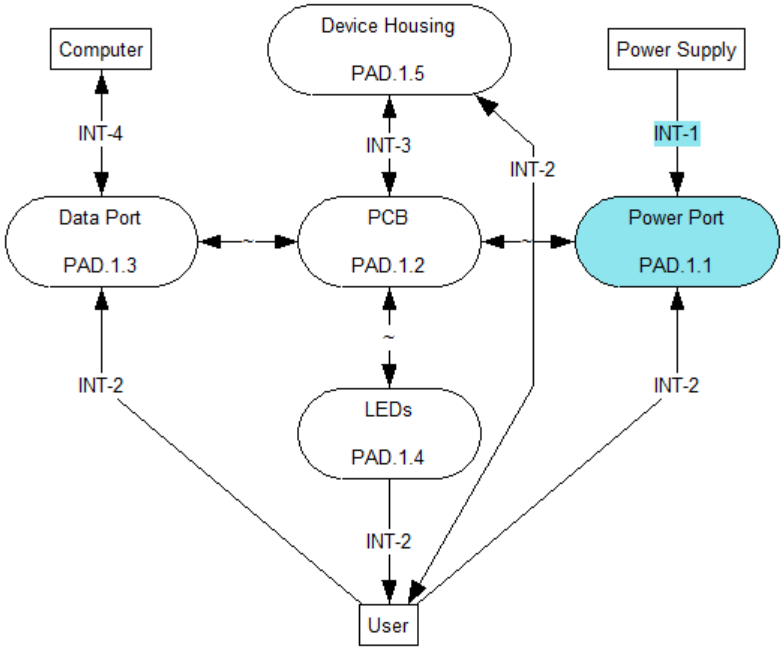
- N/A

Components

PAD.1.1 | Power Port **Status: Firm**

A power port accessible by the user and used to charge the device.

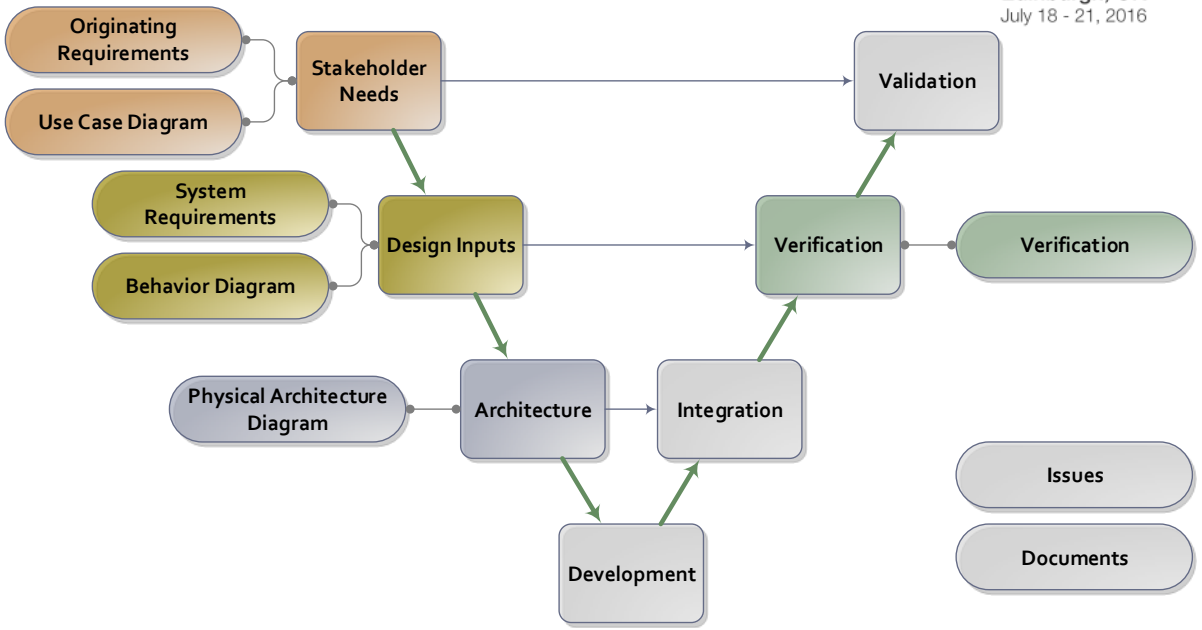
Physical Architecture Diagram



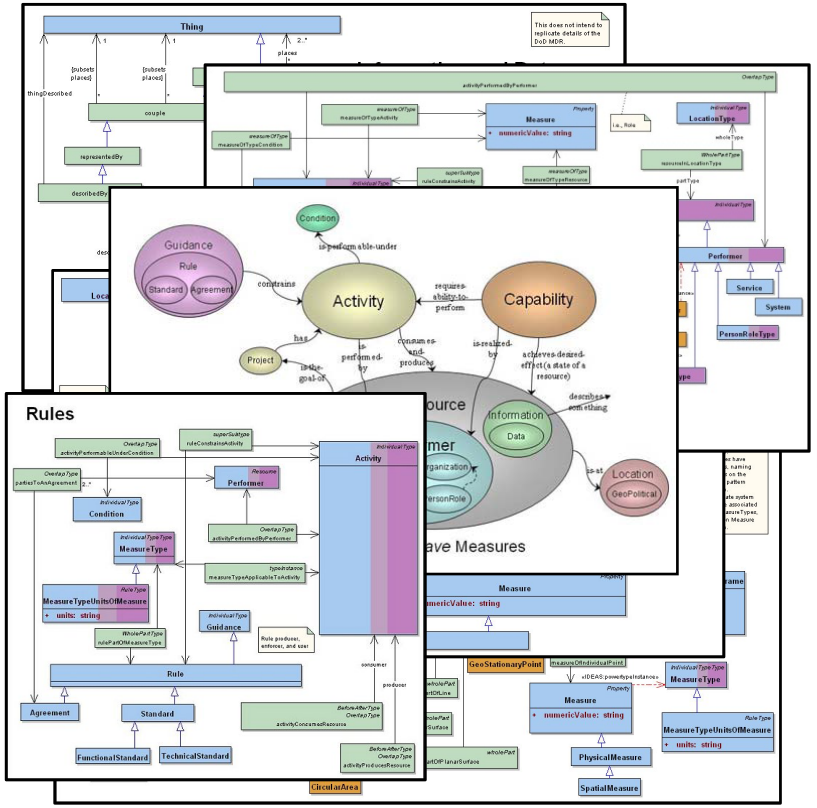
- Re-release Verification Plan

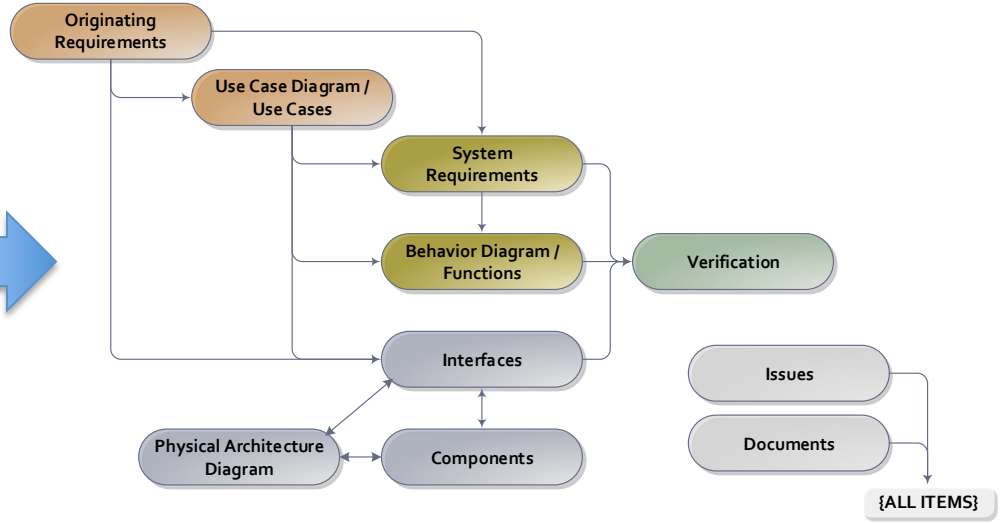
Iterate

- Base model complete
- Refine incomplete items
- Use Documents and Issues



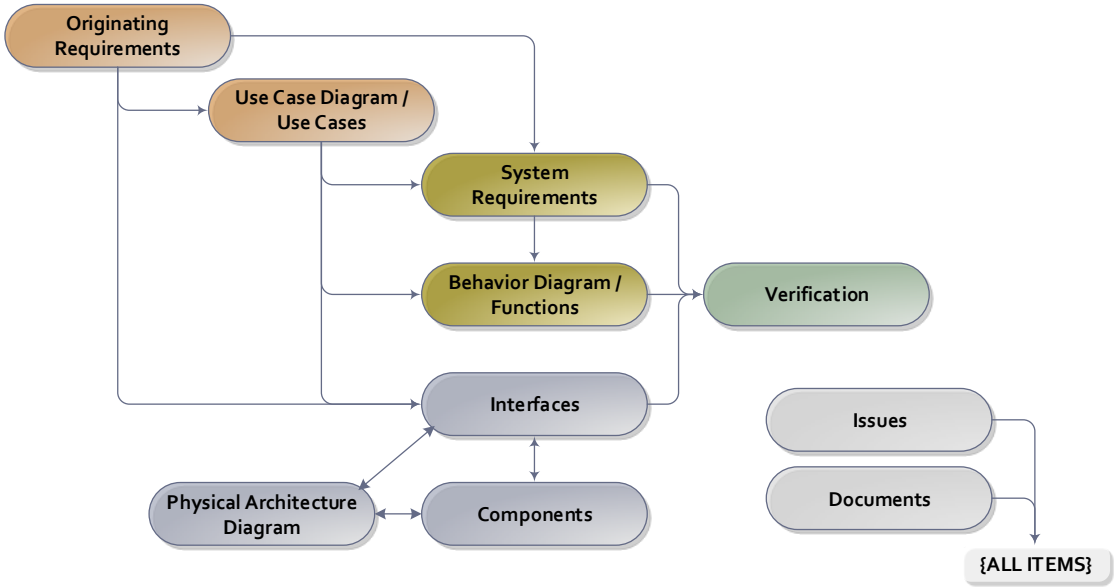
Schema


Thing
Guidance
Rule
Standard
Agreement
Activity
Capability
Condition
Project
Information
Data
Location
GeoPolitical
Rules
Performer
Measure
numericValue: string
MeasureType
MeasureTypeUnitsOfMeasure
units: string
Guidance
Agreement
Standard
FunctionalStandard
TechnicalStandard
PhysicalMeasure
SpatialMeasure
GeoStationaryPoint
CircularArea


Originating Requirements
Use Case Diagram / Use Cases
System Requirements
Behavior Diagram / Functions
Verification
Interfaces
Issues
Documents
Physical Architecture Diagram
Components
{ALL ITEMS}

Go Get Started!

- Setup your schema
- Use your model
- Communicate!
- Show value
- Add items as necessary



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Getting Started with MBSE in Product Development

Nichole Kass

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