TITAN network Swisscom

Numericalpes, Annecy, 06.03.2024

swisscom

Agenda

1. Introduction
2. Testing
3. The Pipeline
4. Resilience tests in production

Introduction

Yann Lollioz, Product Owner Titan

TITAN – The need for IP Networks Simplification

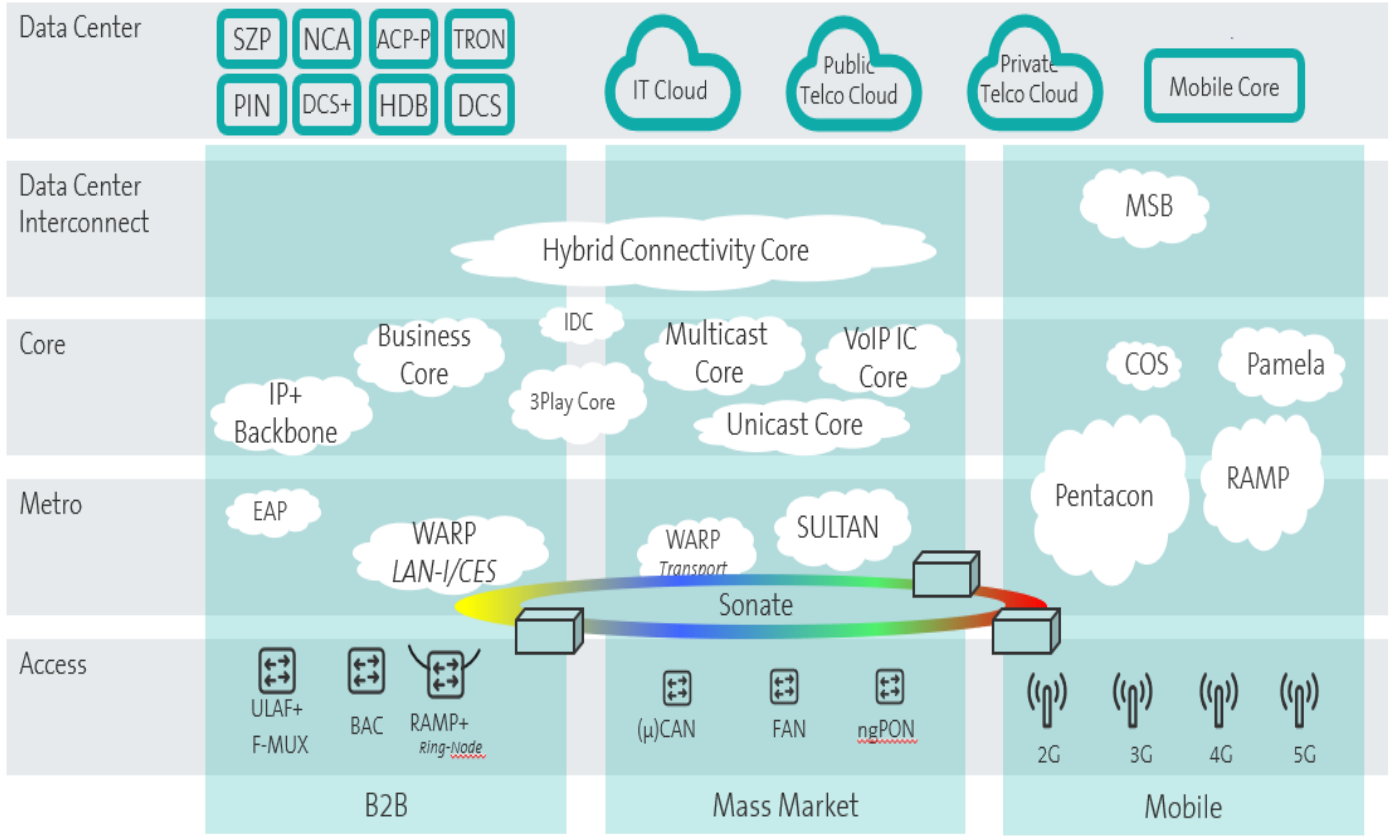
Situation in 2019

- 17 Networks
- 4 Network Equipment suppliers
- Huge number of HW/SW types

Painpoints

- Interoperability problems
- Extreme E2E complexity
- Difficult to automate
- Difficult to monitor E2E
- Engineered/operated by a small group of very specialized engineers (no real DevOps possible)

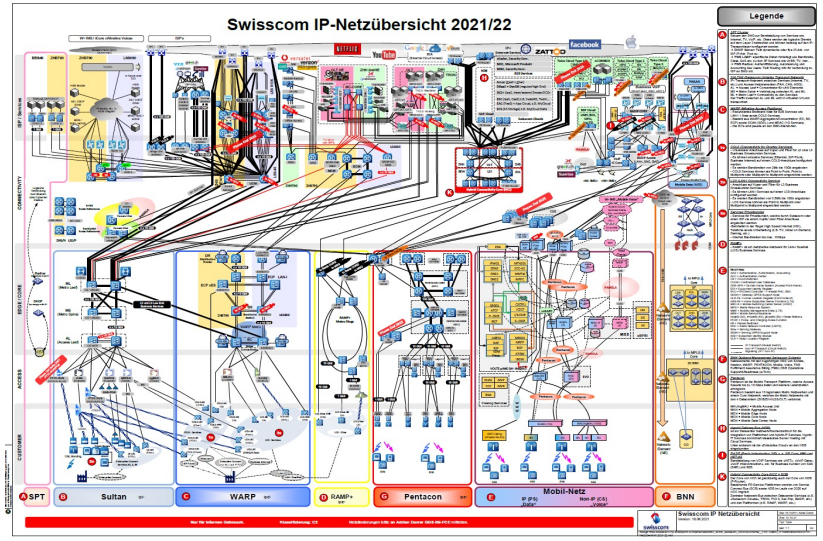
IP Network Overview 2019



TITAN – Network transformation

Alignment of many roadmaps required !

2021



IP Transport Network

- Consolidation
- Simplification
- Standardization
- Automation

Automation Roadmap
(NSO, Monitoring, Testing, CI/CD)

Service Connect Roadmap
(HCC, SC)

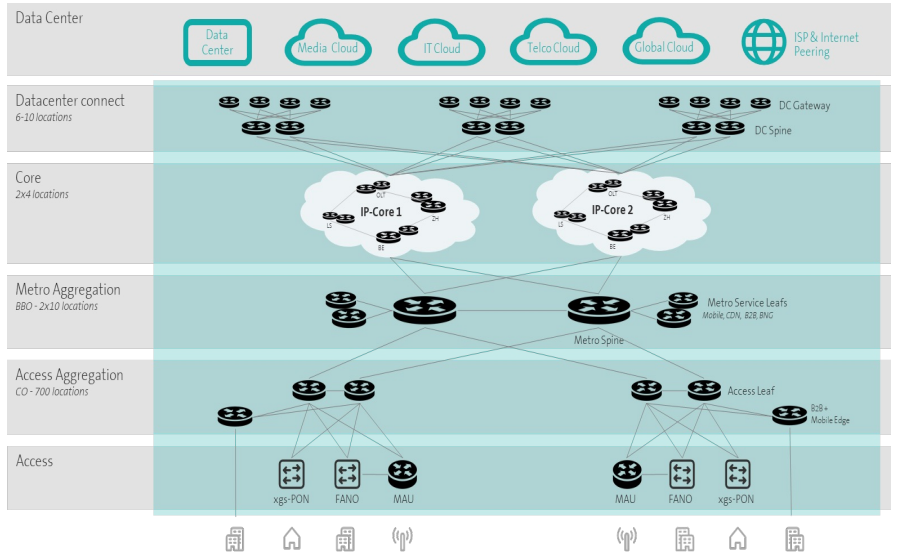
IP Core Roadmap
(UCM, MCM, BCM, MSB, VoIP IC)

B2B Network Roadmap
(WARP, BAC, BPER)

Mobile Transport Roadmap
(Pentacon, Pamela)

Wireline Metro Roadmap
(Sultan)

2026 - TITAN



Consolidation

- a single, high-available network
- single vendor with shared responsibility
- standardized HW and SW portfolio

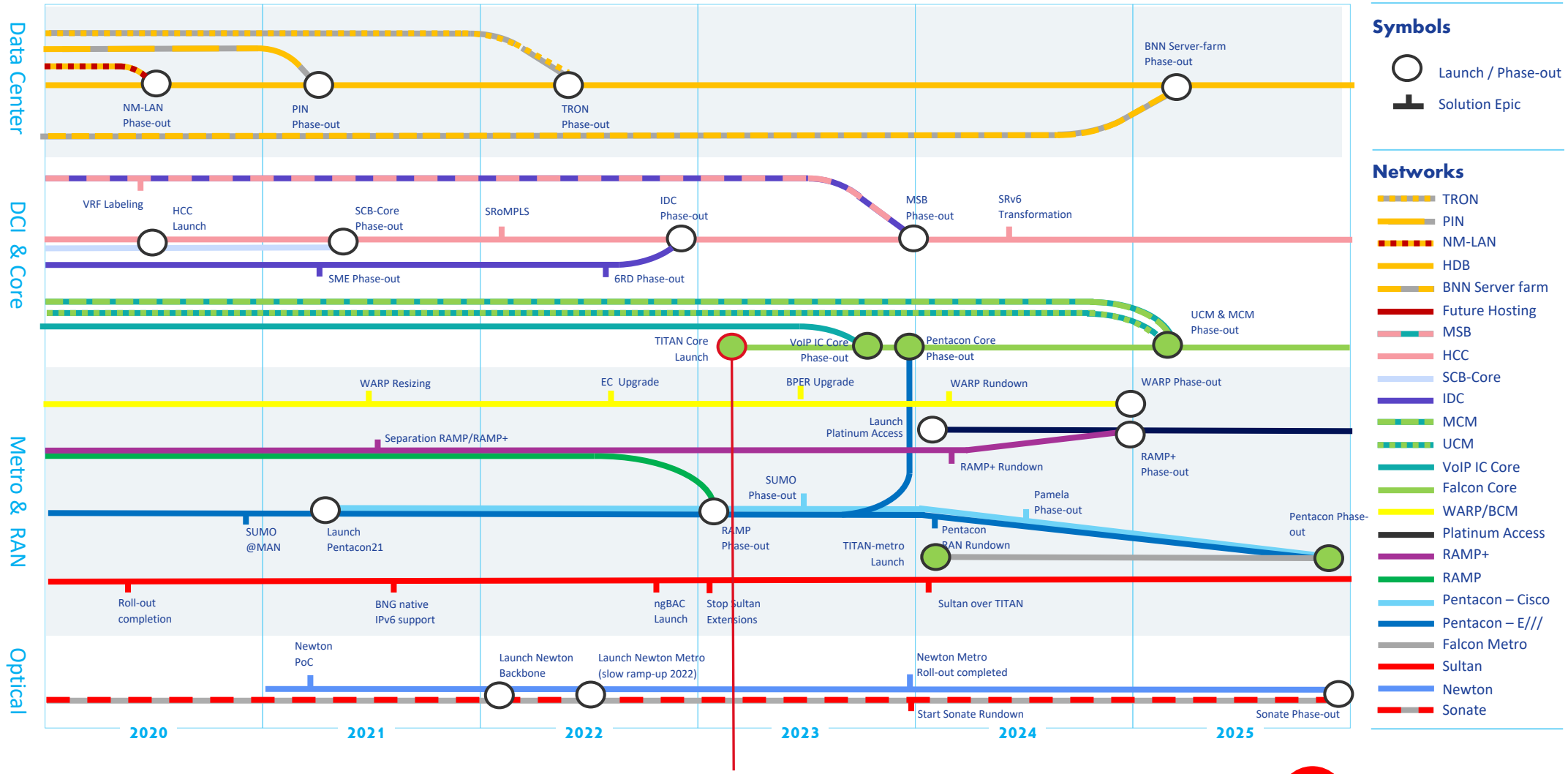
Simplification with new Technology

- from MPLS to SRv6
- from IPv4 to native IPv6

Automation

- Network as a Service
- Fully automated CI/CD pipelines

TITAN – Transport Network consolidation map

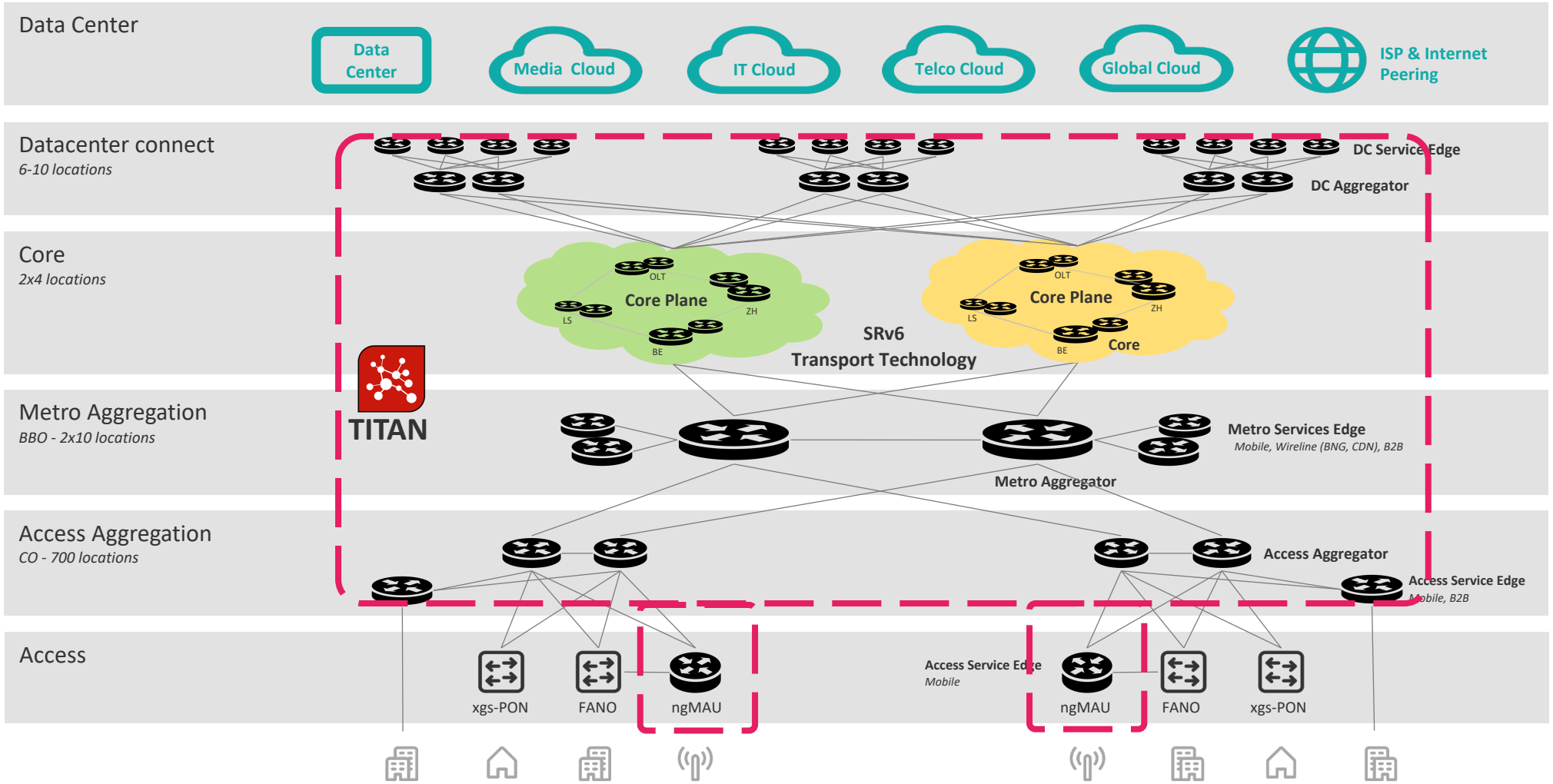


VALUE STREAM
NETWORK CONNECTIVITY

TITAN

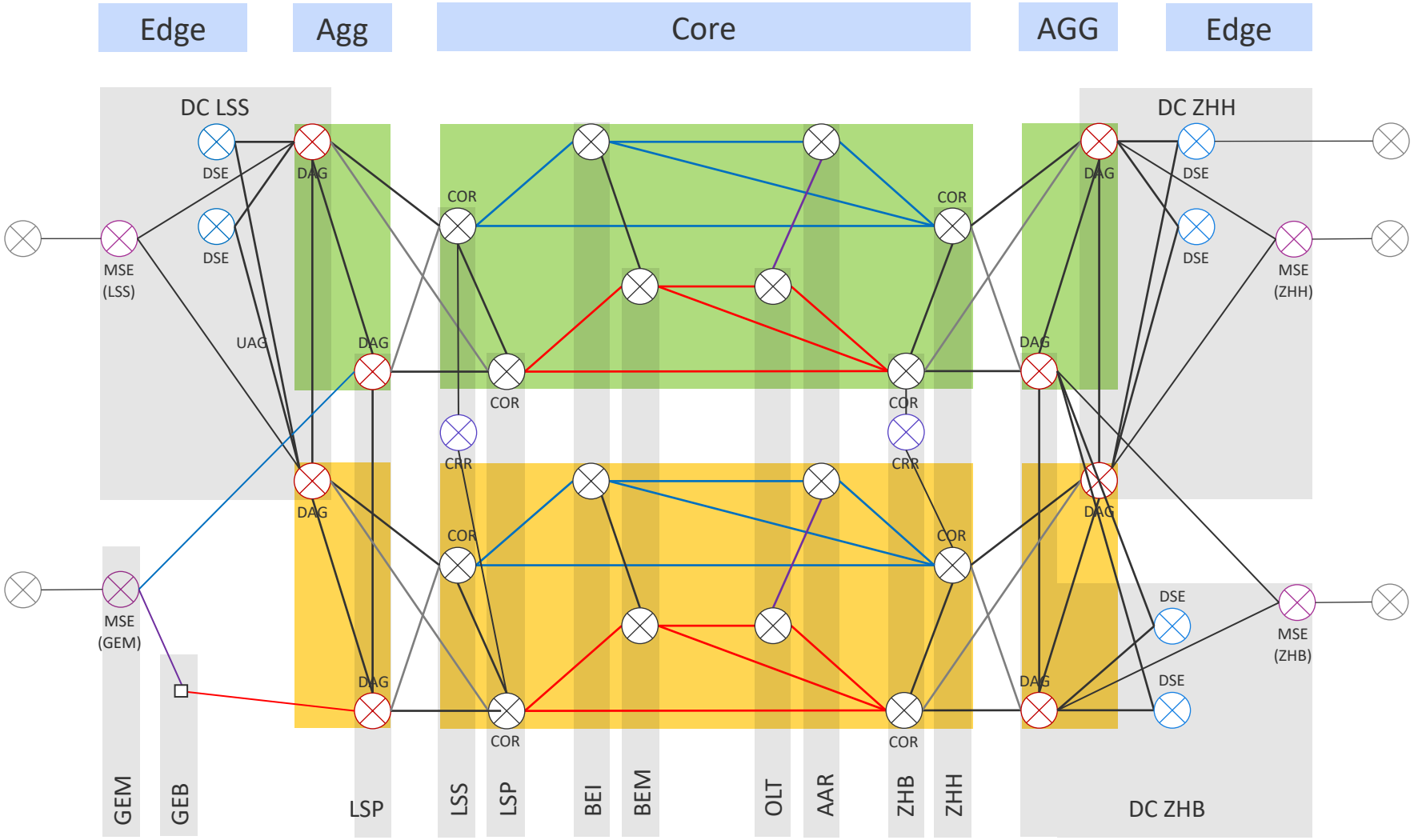
BEST NETWORK
TRANSPORTNET OF SWISSCOM
EVERY CONNECTION MATTERS

TITAN – Target Architecture 2026



TITAN – Overview

Without metro



Core
8202-32H-M

DSE
ASR9903

MSE
NCS540

DAG
8202-32H-M

CRR
ASR9902

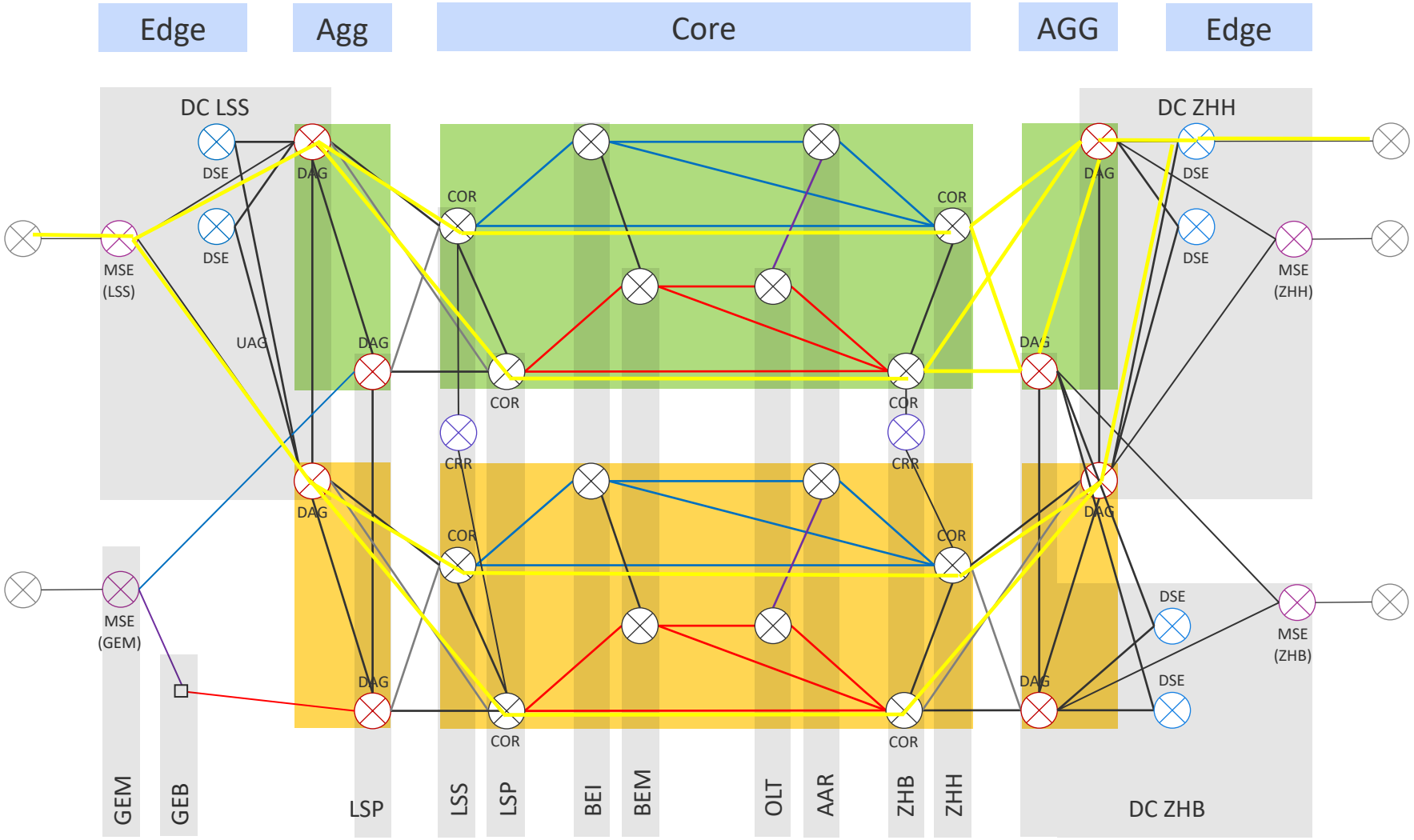
NEWTON Node

Customer

NEWTON Red Plane
NEWTON Blue Plane
NEWTON Interplane
Darkfiber inhouse (<2 km)
Darkfiber (<10 km)

TITAN – Overview

Traffic flows



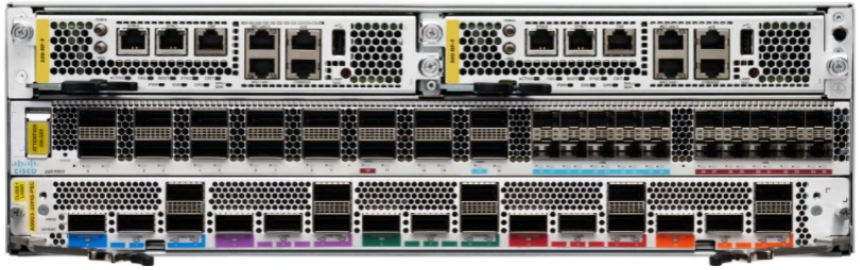
TITAN Dual Plane Core
two parallel systems increase availability and double the number of 9s!

- two redundant planes (**green**/**orange**)
  - planes not *physically* connected **(data-plane separation)**
  - planes not logically connected (IGP) **(control-plane separation)**
  - planes used active/active for all services (**BGP multipath** possible**)**
- load-sharing between 4 best paths in normal operation
  - 2 in green plane
  - 2 in orange plane
- no concurrent maintenance work on both planes

TITAN – Service Edge Routers Hardware

8202-32FH-M (CORE, DAG)

ASR9903 (DSE)



NCS540-ACC-SYS (MSE)

ASR9902 (RR, *DSE*)

Core & Datacenter Aggregator (DAG)

- Non-modular chassis
- 32 x 400Gbit/s Interfaces
- Power consumption ~700W per device

Datacenter Service Edge (DSE) = ASR9903

- 2 x RP, integrated switch fabric
- redundant fans
- fixed linecard ports — 14 x **100G** QSFP28 and 20 x **10G** SFP+
- modular linecard ports — 5 x **400G** QSFP-DD or 20 x **100G** QSFP28 (total 2 Tbps)

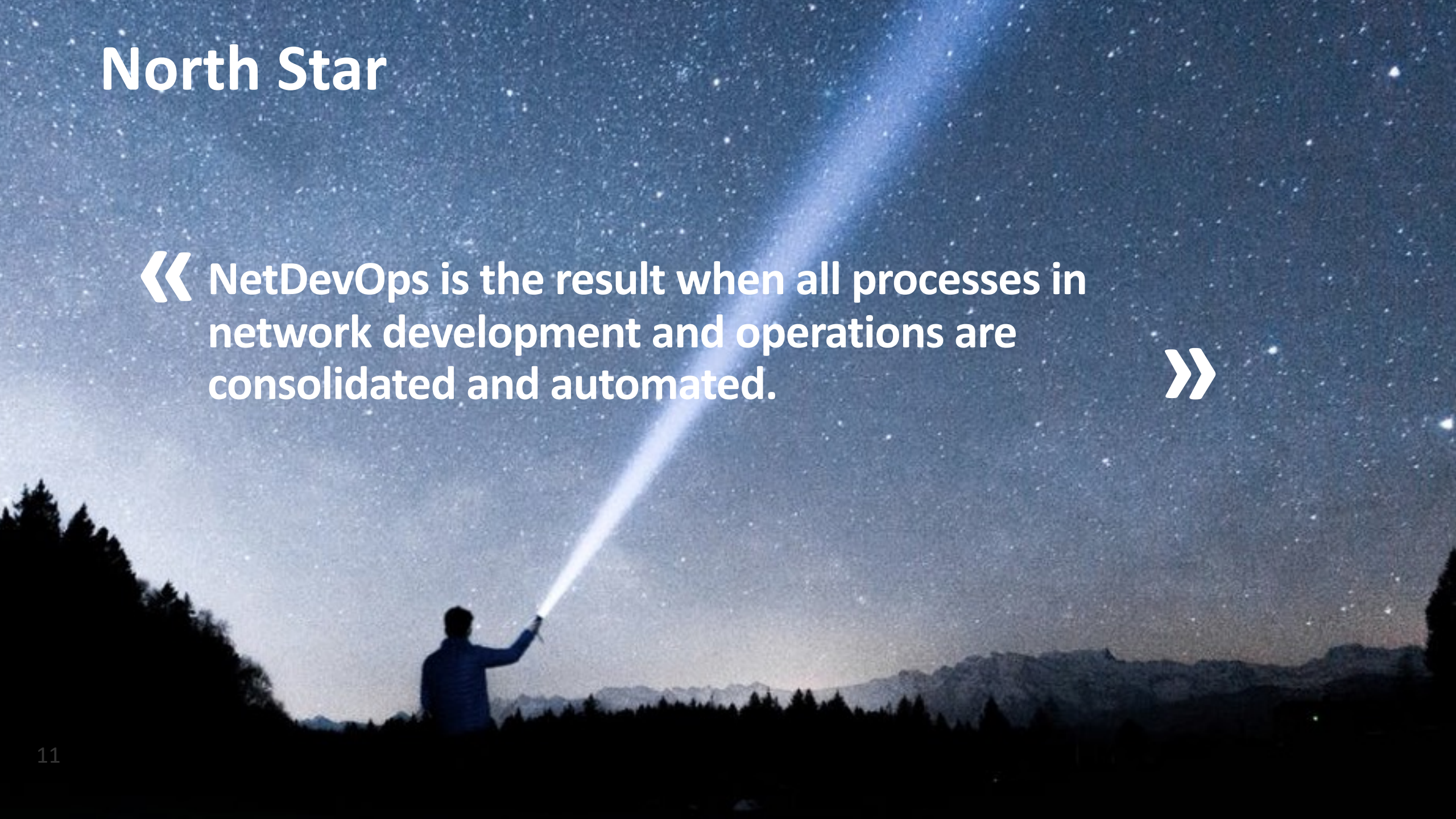
Metro Service Edge (MSE) = NCS540-ACC-SYS a.k.a. Tortin

- 3 + 1 redundant fans
- forwarding performance: 300 Gbps
- ports
  - 2 x QSFP-DD **100G** / 40G — used towards Core node
  - 8 x SFP+ 25G / **10G** / **1G** — used towards OLO
  - 24 x SFP+ **10G** / **1G** — used towards OLO

Route Reflector (RR) = ASR9902

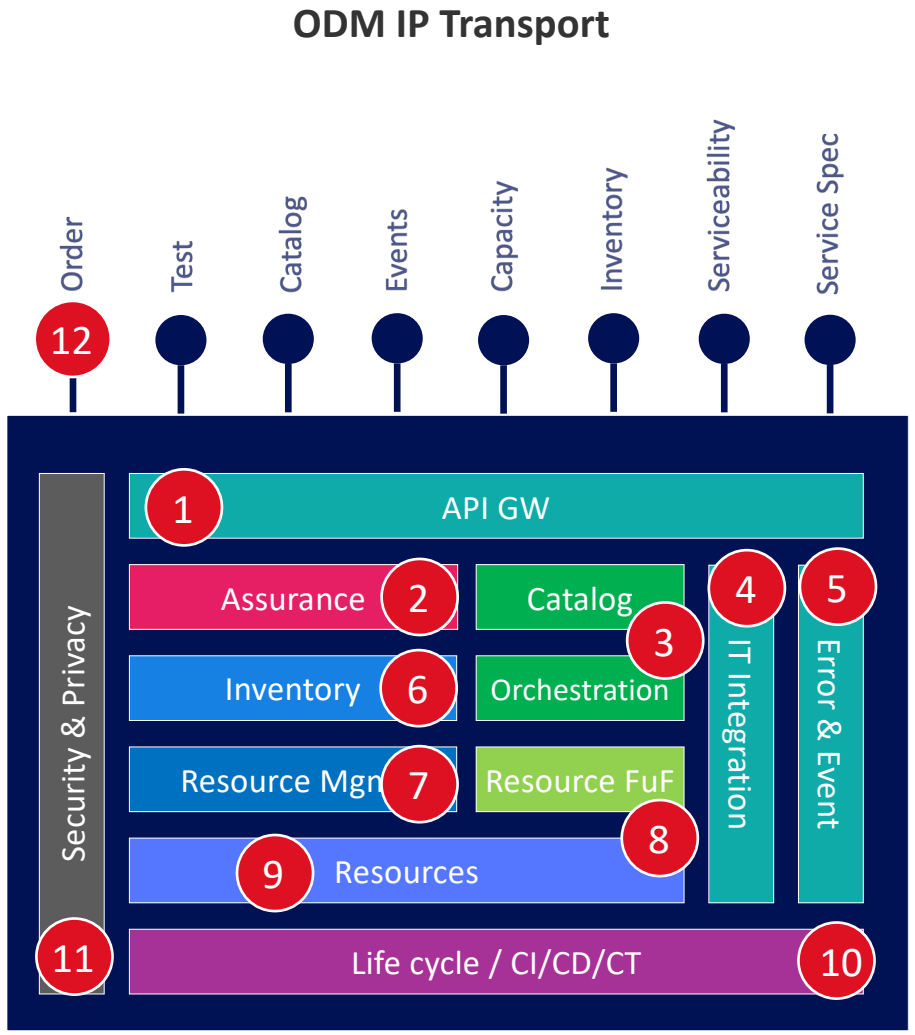
- 2 x RP, integrated switch fabric
- 2 + 1 redundant fans
- ports
  - 2 x QSFP-DD **100G** / 40G / 10G
  - 6 x QSFP28 100G / 40G / 10G
  - 16 x SFP28 25G / 10Gb
  - 24 x SFP+ 10G

North Star



« NetDevOps is the result when all processes in network development and operations are consolidated and automated. »

TITAN – IT Solution Design



1. **Apigee** (Digital Market Place) (wip)
2. **Netcool / Daisy**
3. **Thor & CP Broker**
4. **REST API / Kafka SBD**
5. Jaeger (API event logging) (exploration)
6. **NDO** (Netcracker)
7. **NSO** (Cisco)
8. **Zeebe Camunda**
9. Titan Network, Telemetry
10. Jenkins, GIT, Artifactory, **NTM**
11. Security Access controls (Accounts, Geofencing) (wip)
12. Standardized L2/L3 VPN Connectivity API

TITAN - Improve and automate network operations

Our journey to NetDevOps

1

Manual Ops

- **Ad-hoc scripting**
- Operations at the device level
- Silo knowledge
- Low standardization

2

Automated Workflow

- **Focus on troubleshooting**
- Lots of preparations before change needed
- HW / SW homologation
- Some tests are automated

3

Automated tests and network as code

- **Infrastructure as code (git)**
- Test driven Ops
- Rethink troubleshooting as testing
- Implementation of telemetry and analytics
- Automated capacity mgmt.
- Network service model

4

CI/CD Ops

- **NetDevOps model**
- Pipeline for accuracy and agility
- Feedback/fail loop, small changes and frequent deployments
- Observability (metrics, tracing, logging) is the new monitoring
- Starting to automate Root Cause Analysis

5

Outcome driven

- **Business process orchestration**
- Network Reliability Engineering with Service Level Indicators, Objectives, and Agreements (SLO,SLI, SLA)
- Effective usage of error and toil budget
- Manage dependencies, separation of concerns
- Automated Root Cause Analysis
- Integrate Customer Care trends as a feedback loop

Foundation

People

Focus on reliability and value for the customers.

Combine IT & networking skills

Process

NetDevOps and NRE

Technology

Test automation & CI/CD pipelines

Service modelling (NaaS)

TITAN - Network Development Process (Automated CI/CD)

yesterday

today

Step 1

Network engineer:

- develops router config
- writes engineering manual

Network element, Word

Step 2

Software engineer:

- reads engineering manual
- writes config template and IT spec

Word, Excel

Step 3

External Software developer:

- writes code and delivers to Swisscom

FUF tool

Step 4

Software and Network engineer:

- manually test code in lab

FUF tool , network element

Step 5

Software engineer:

- deploys code

Network Engineer:

- triggers network update

FUF tool , network element

---

today

tomorrow

Step 1

DevOps Engineer:

- develops router config
- adapts templates and writes glue code

Network element, NSO

Step 2

DevOps Engineer:

- commits code
- Automated tests are run

NSO, git, jenkins

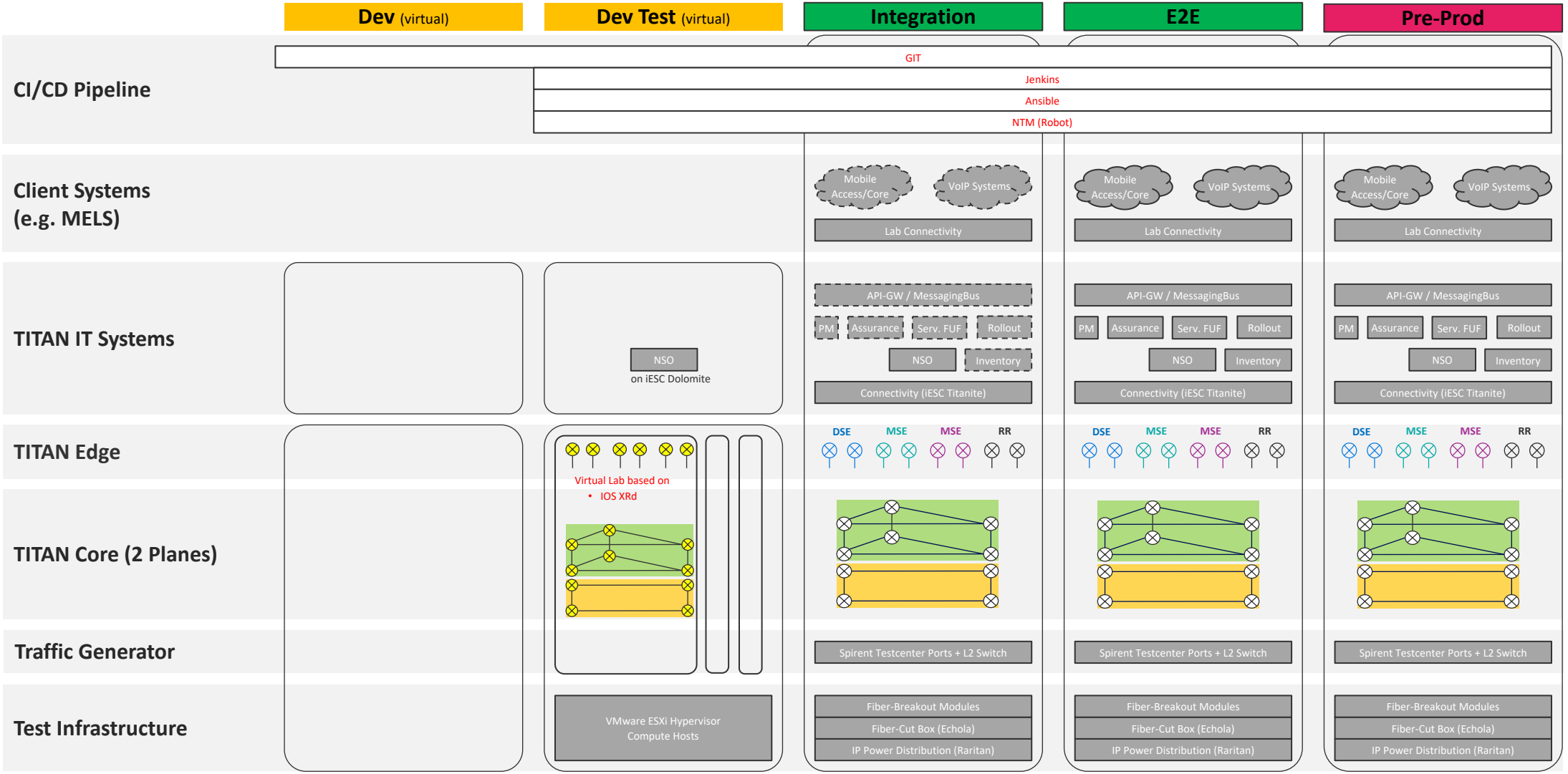
Step 3

DevOps Engineer:

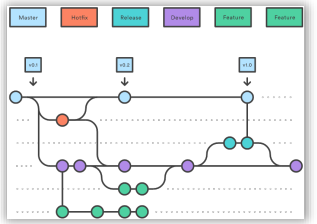
- deploys code
- live network is updated

NSO, Network element

TITAN – IPT ODM Lab Stages



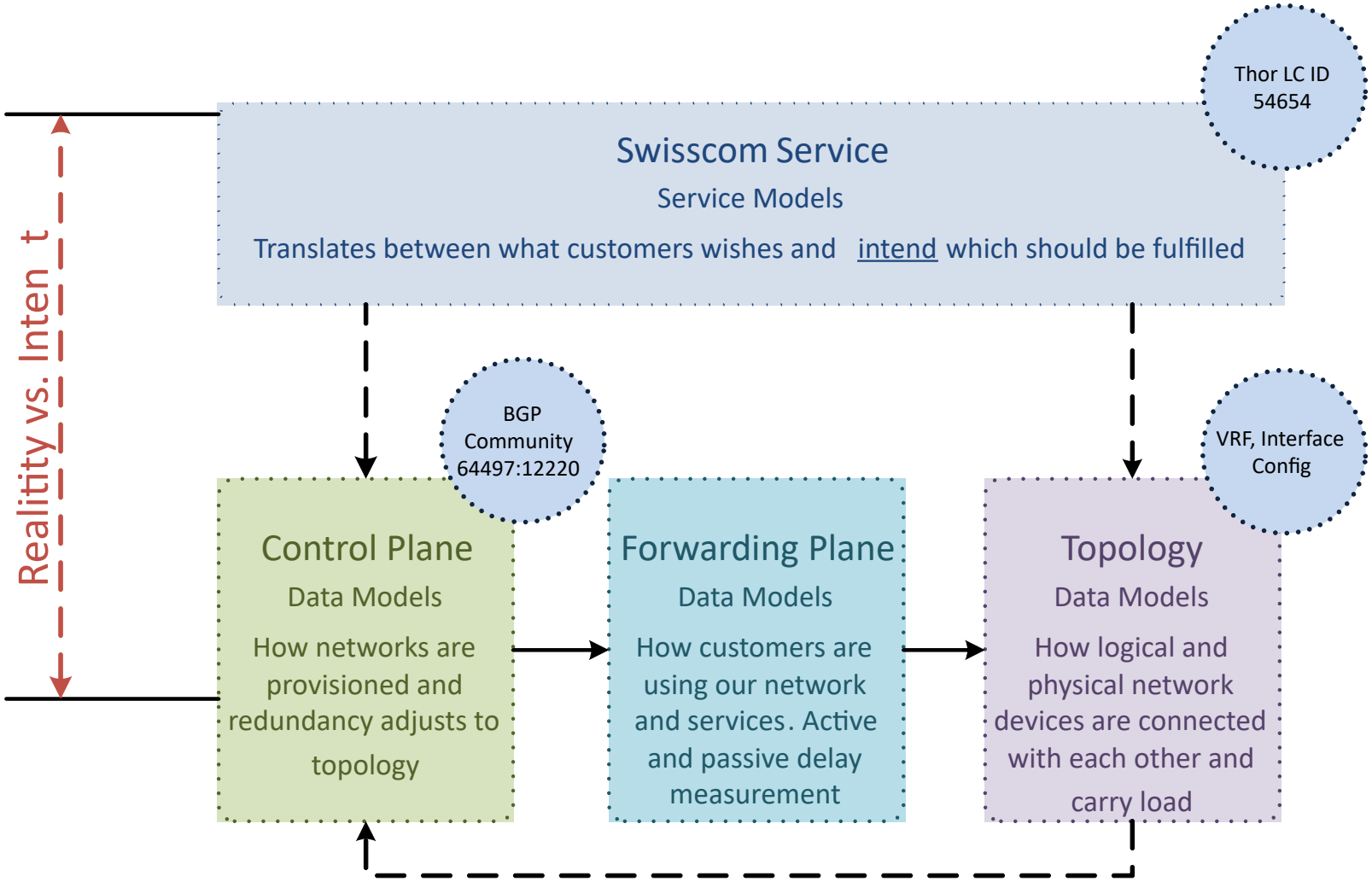
TITAN – Delivery methodology



Stage	Dev	Dev Test Labs	Integration Labs	E2E Labs	Pre-Production Labs	Production
	GIT Checkins	Automated	Environment Manager	Environment Manager	Change Board	
Domain / Building Block	Development	Development Code	Development Code	Release Candidate Code	Released Code	Released Code
		TITAN NSO DevTest Lab	TITAN Integration Lab	TITAN E2E Lab	TITAN Pre-Production Lab	TITAN Production
		DevTest Pipeline	Integration Pipeline	E2E Pipeline	PreProd Pipeline	Prod-Test-Sites Pipeline Prod-Pilot-Sites Pipeline Prod-All-Sites Pipeline
Pushed **feature branch commit** triggers the pipeline	auto	Feature Builds				
Development branch commit or merge triggers BOTH pipelines	auto	Development Builds				
Release branch commit or merge triggers BOTH pipelines	auto	Release Candidate Builds		manual Release Candidate	manual Release Candidate	manual Release
Hotfix branch commit or merge triggers Dev Test pipeline only	auto	Hotfix Builds	Hotfixes should not exist when main process is fast enough			Solution Hotfix

TITAN - Data Collection with Network Telemetry

Structured metrics enable informed decision-making



Network Telemetry:

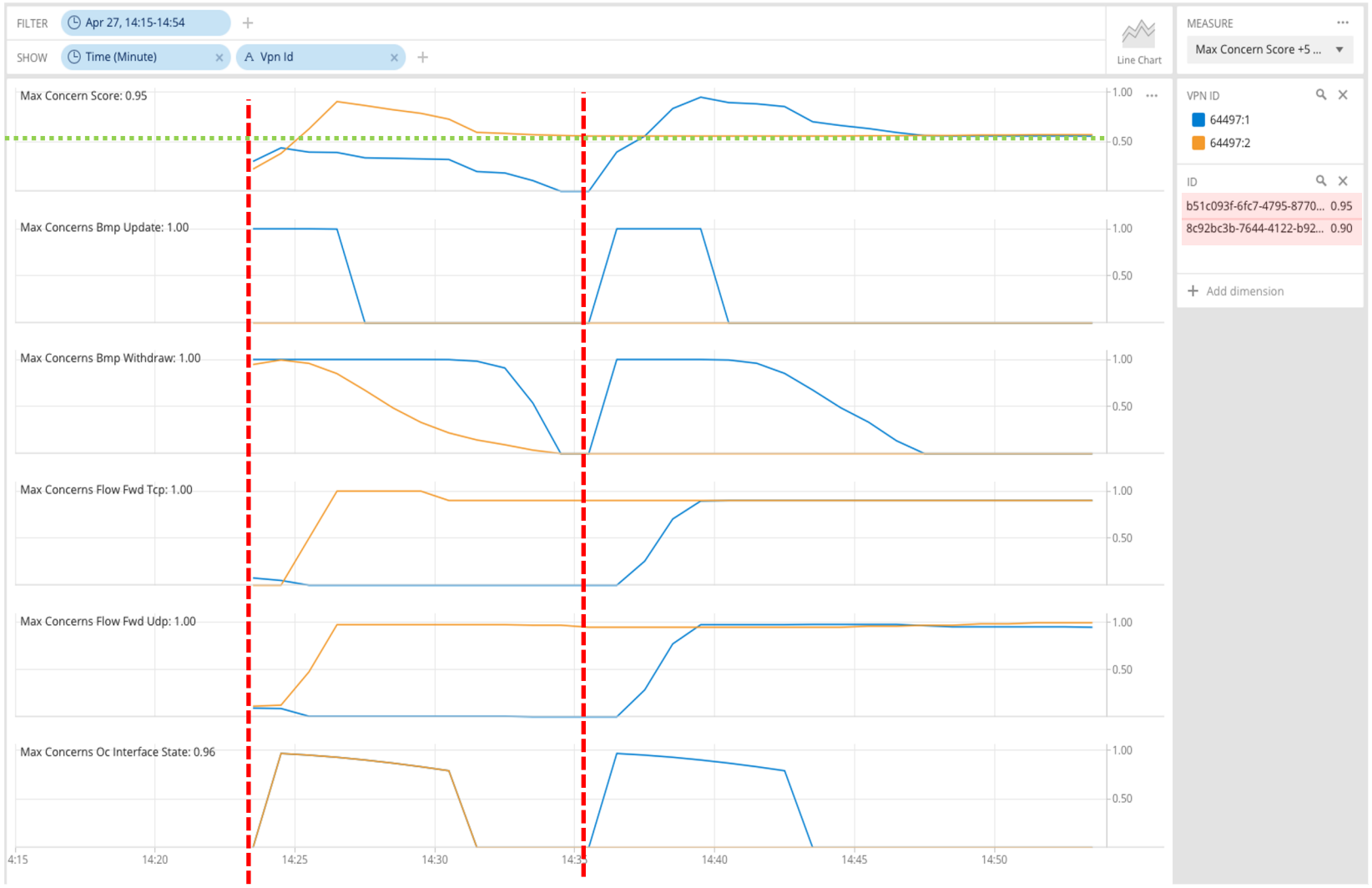
> A data collection framework where the network device pushes its metrics to Big Data. Defined in RFC 9232.

Data Modelling:

> Key for Big Data correlation to understand and react in the right context
>
> > Are interface drops bad?
> >
> > How should we react?

TITAN - L3 VPN Network Anomaly Detection

Networks are deterministic – customers partially



Analytical Perspectives

Monitors the network service and wherever it is congested or not.

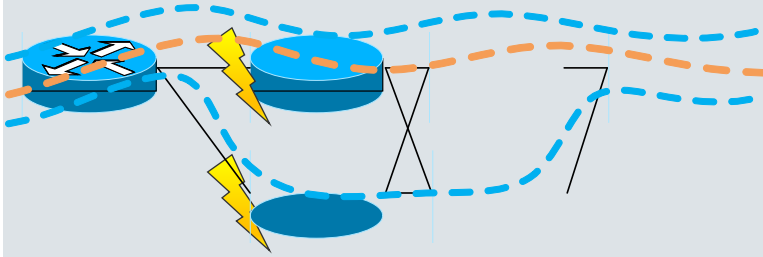
- BGP updates and withdrawals.
- UDP vs. TCP missing traffic.
- Interface state changes.
- Developed and refined in collaboration with the IETF community. Presented at the Applied Network Research Workshop 2023.

Network Events

1. VPN orange lost connectivity.
   VPN blue lost redundancy.
2. VPN blue lost connectivity.

Key Point

- AI/ML **requires** network intent and network modelled data to deliver dependable results.



- Anomaly detection is developed and refined in collaboration with the IETF community. https://hal.science/hal-04307611

LAB Tour

Paul Gantner, Product Owner BBLAB

BBLab – Lab Tour

Facts & Figures

- Area of Lab's > 1000m2
- Total 360 System-Racks (without Cross-Patch-Racks), ca. 90% in Containments, ca. 10% "non Containments"
- Area „Testing Workshops" ca. 230 m2
- ca. 600 kW Power Consumption (570 AC / 30 DC)
- Fix-Cabling (Fibre & Copper) total ca. 300 km
- ca. 650 active Lab User Accounts
- ca. 250 Lab User VM's
- Dedicated Lab-Net incl. IN- & Outband-Mgt, Remote-Access, etc
- 20 Server (Web, DHCP, DNS, FTP, Inventory & IP Adress-Mgt, Reservation-Tool, Power-Mgt, AAA, Monitoring, etc)

Testing in action

Bartlomiej Bacal, Network Engineer Titan

TITAN – Automated Testing (i)

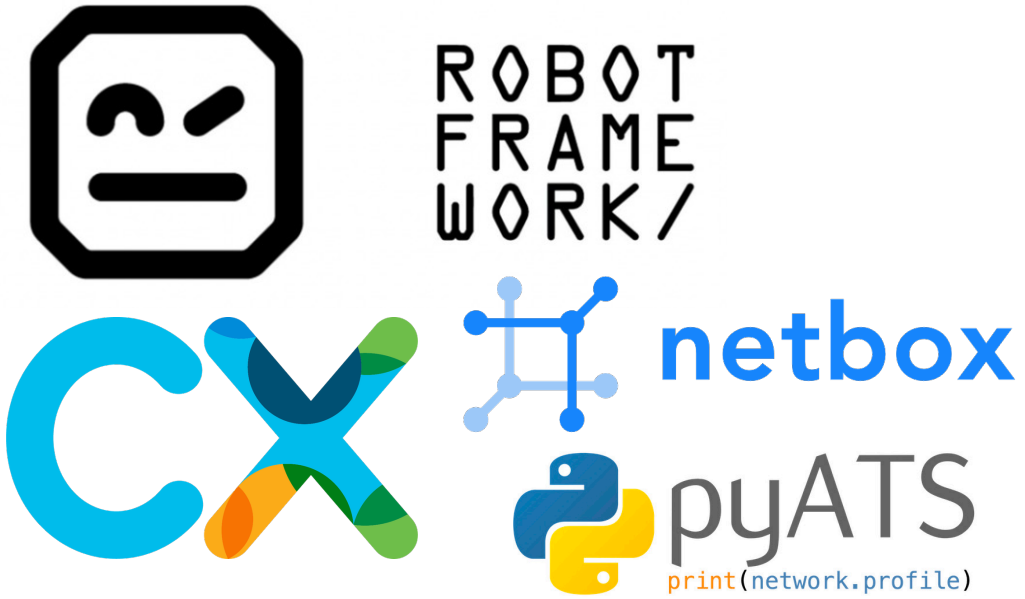
Extended Capabilities

- Traffic Generators
- Layer 1 Optical Switches
- Intelligent PDUs
- Network Packet Broker
- Network Analyzer/Multimeter
- Time-Sync Test Instruments

TITAN – Automated Testing (ii)

Overview

- Robot Framework and CX Test Automation
- CX Test Automation Manager
- NETCONF/YANG
- REST APIs
- Testbed and topology built based on SoT



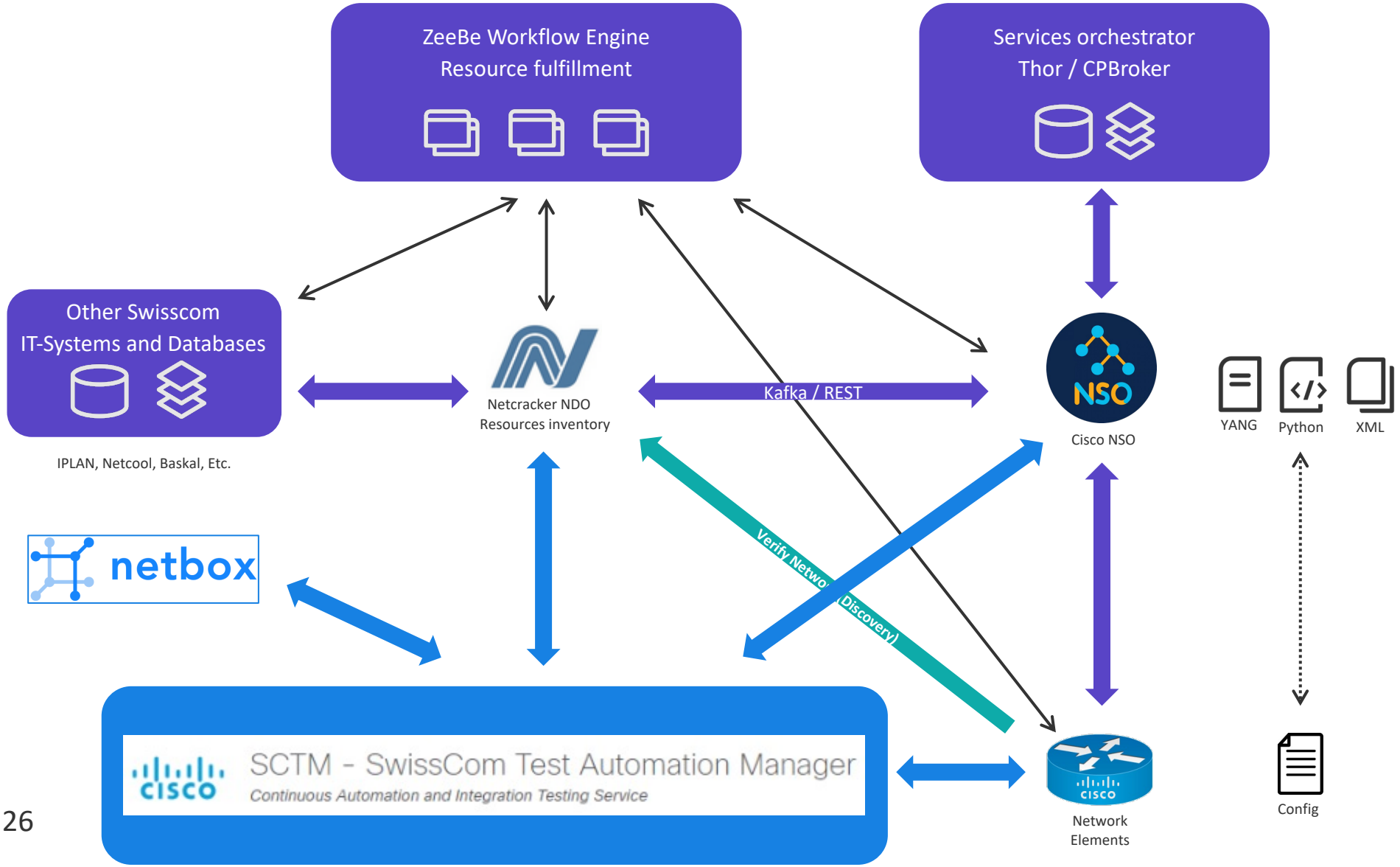
TITAN – Automated Testing (iii)

Use Cases

- Regression Tests
    - Functional
    - Convergence
    - Scalability
    - End-To-End process
- Feature Acceptance Tests
- Unit Tests (NSO-Arc, Robot Keywords)

```
*** Settings ***
Library  Collections

*** Variables ***
${hostname}  asr9k-1

*** Keywords ***
This is my custom Keyword
    Log  "This is a custom Keyword"

*** Test Cases ***
First step
    Log  This is my hostname ${hostname}

Second step
    This is my custom Keyword
```

TITAN – IT Landscape



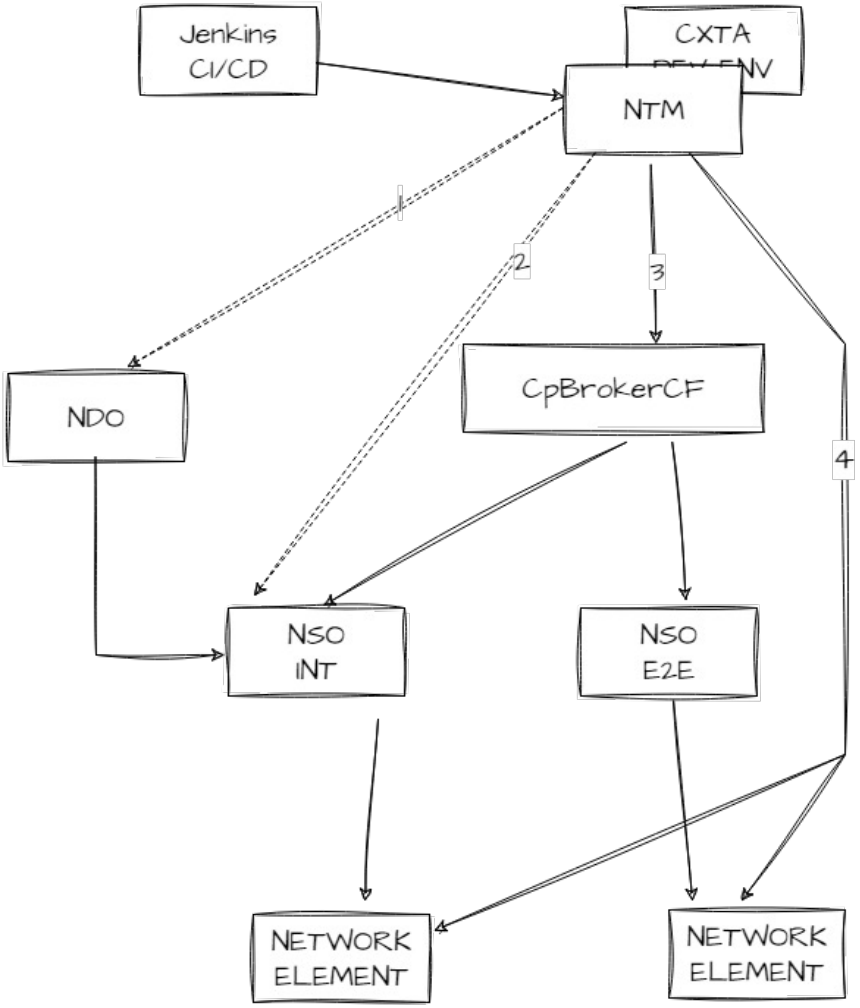
Device configuration parts:

- **Day0** - Basic configuration
  (Remote access, logging, alarming, etc.)
- **Day1** - Network underlay
  (Links, bundles, basic routing IGP)
- **Services** - Network overlay
  (L3VPN, L2VPN, etc.)

TITAN – Automated Testing Demo

Service Fulfillment

- Used for the provisioning of L3VPN
- Multiple Systems/Interfaces involved
- Regression test for NSO release candidate

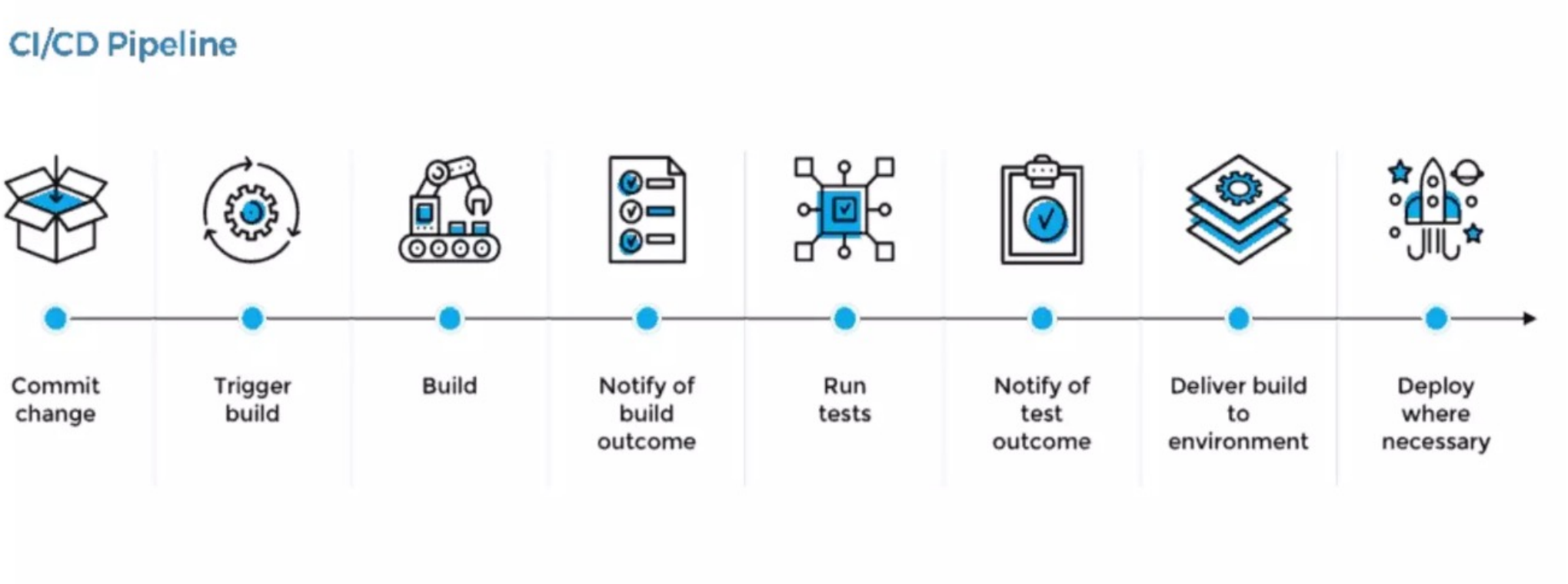


CICD Demo

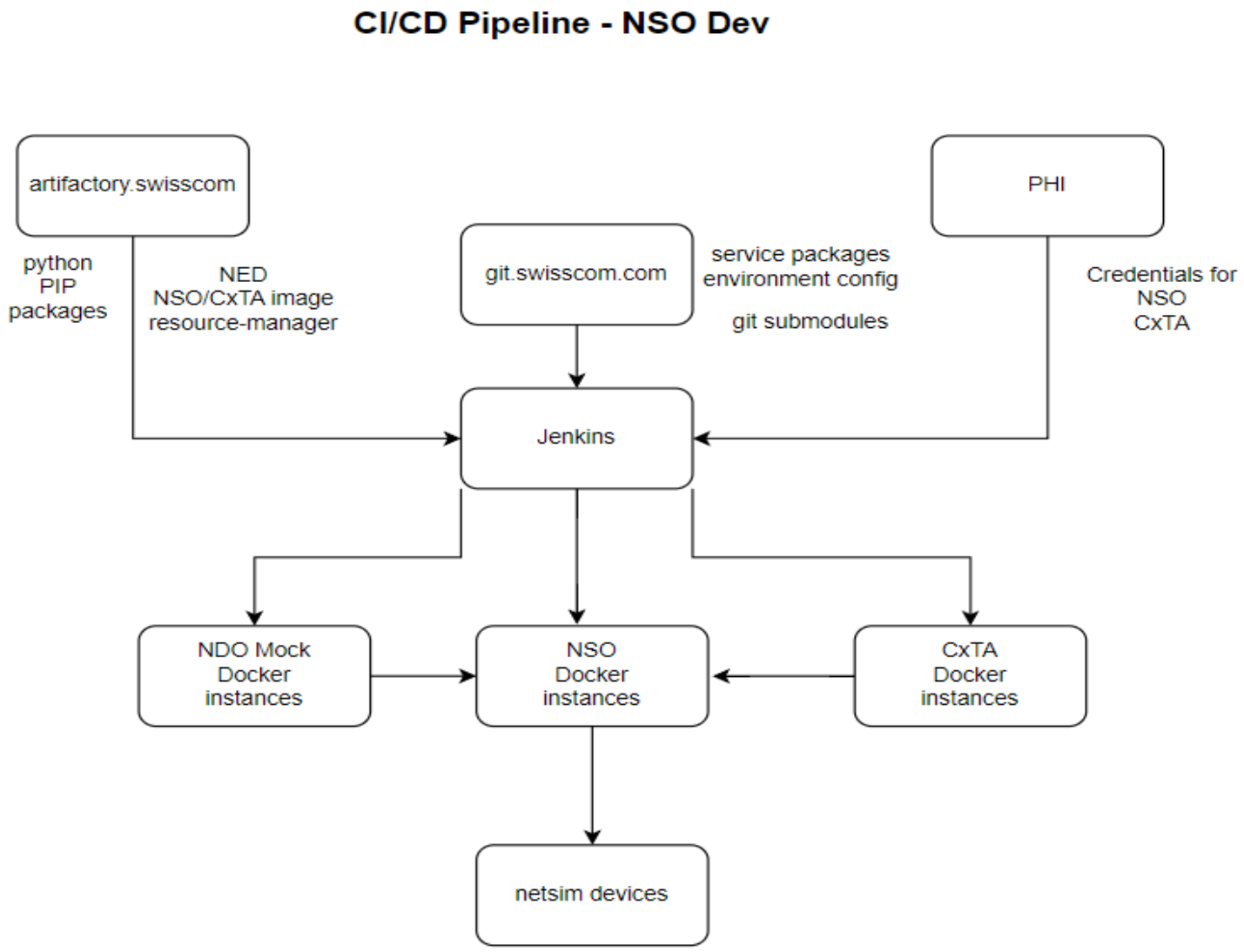
Eugen Serban, DevOps Engineer Titan

CICD Pipeline

- CICD pipeline is important to deliver a qualified software products on time.
- When a developer integrate their code into a common repository, series of steps where automated to push the code to artifactory then it will be used to in other environments.



TITAN – DEV Pipeline Showcase



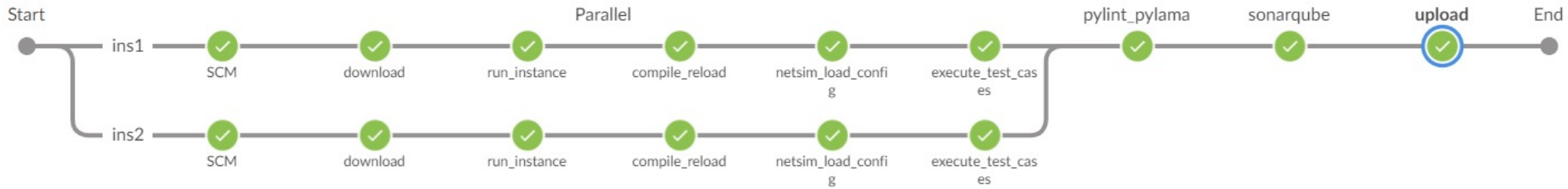
CICD Pipeline - Dev

nso / titan_services

Commits

develop ···

	Author	Commit	Message	Commit date	Notes	Issues	Builds
	Serban Eugen, INI-NET-V...	c47a1ce7dcb	Pull request #498: Bugfix/TPN-7079 c9000v option Merge in NSO/titan_services from bugfix/TPN-7079-c9000v-option to develop Squashed commit of the following: commit dbdb5b17a75e0abb574e0d673576bd1410eb92e8	5 days ago		TPN-7079	✓
	Gysi Martin, INI-NET-VN...	590862286db	Pull request #499: Bugfix/TPN-7154 remove hw module Merge in NSO/titan_services from bugfix/TPN-7154-remove-hw-module to develop Squashed commit of the following: commit ce41631fbe40207833a6fa068323d51f02fb	1 week ago		TPN-7154	!
	Natarajan Sundaravel, IN...	416c1e347c6	Pull request #492: revert back the change Merge in NSO/titan_services from bugfix/TPN-7161-ndo-nso-sync-revert to develop Squashed commit of the following: commit acf75f1f1905a4f10047195dfc26845a9722bdab Merge: a	1 week ago		TPN-7161	✓



ACCESS-PORT NSO-SERVICE BAC	40	33	0	7	00:04:25	
Access Port on des device	3	3	0	0	00:00:04	
Access Port on met device	3	3	0	0	00:00:03	
bac-day1 NSO-SERVICE BAC	42	17	0	25	00:01:25	
Base BGP topo on MainInterface	3	3	0	0	00:00:04	
BGP DSE-SMEN peering	3	3	0	0	00:00:05	
BGP Max Prefix Warning Only	3	3	0	0	00:00:04	
BGP redistribute local interface network into BGP	3	3	0	0	00:00:04	
BGP weight	3	3	0	0	00:00:03	
Direct Connection Point	3	3	0	0	00:00:02	
Direct Connection Point, no HSRP	3	3	0	0	00:00:02	
Direct Connection Point, VLAN 4000	3	3	0	0	00:00:02	
KAFKA-PRODUCER NSO-SERVICE	4	4	0	0	00:00:41	
Multiple Connection Points	6	6	0	0	00:00:07	
RFS Base Aggregator	3	3	0	0	00:00:02	
RFS Base Core	3	3	0	0	00:00:02	

CICD Pipeline - Integration

•Jenkins will listen to an Artifactory URL if new files where uploaded then jenkins will trigger the build execution

•In Integration environment, Jenkins will do the same steps but in a different platform. Its not dockerized instances and real network elements were connected and different clusters are using NSO application.

•Integration pipeline mainly focused for 2 branch groups,

- •Develop
- •Release

Pipeline integration

Full project name: titan_pipelines/integration

Add description

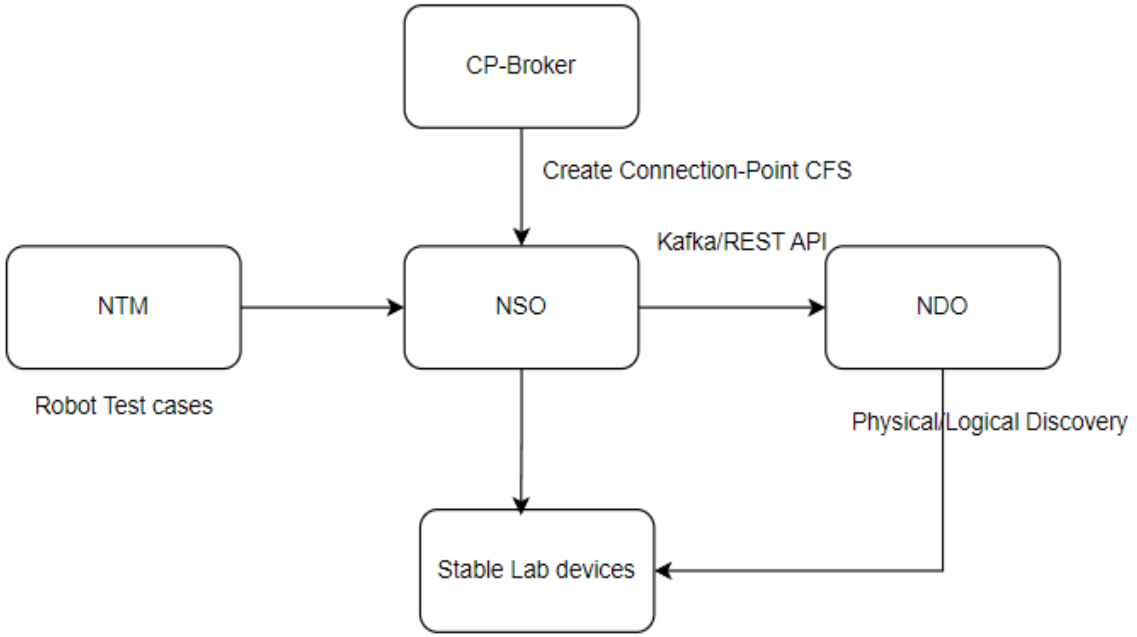
Disable Project

Stage View

	check-HA	checkout on Master	checkout on Slave	PHI password retrieval on Slave node	backup packages	download	compile	reload-slave	reload-master	CXTA test	upload	revert packages on slave	revert packages on master	VIP check
Average stage times: (Average full run time: ~16min 44s)	1s	12s	2s	31s	2min 7s	40s	3min 17s	5min 6s	3min 2s	49s	5s	0ms	0ms	574ms
#435 Jan 19 12:12 1 commit	1s	8s	1s	27s	2min 1s	36s	2min 49s	2min 49s	3min 6s	51s	5s			578ms

CICD Pipeline – E2E

- In E2E by principle only release branch code will be deployed.
- E2E will be deployed manually by selecting the required release branch.
- E2E NSO application connected with E2E stable Lab devices.



Pipeline E2E

This build requires parameters:

RELEASE_NAME

Select your release to deploy ?, if your release is

Update Release List

Update Release List
release-2.1.19
release-2.1.18
release-2.1.17
release-2.1.16-upgrade-fix
release-2.1.6-pre-mod-test
release-2.1.16

CICD Pipeline - Operations

- Jenkins job will take the backup of NSO application,
  - Daily basis
  - Weekly basis
  - Monthly basis
    - From Integration to Production environments
    - We can restore the environment using these backups.
- Jenkins job is executing "platform test cases" for every week on Integration environment.

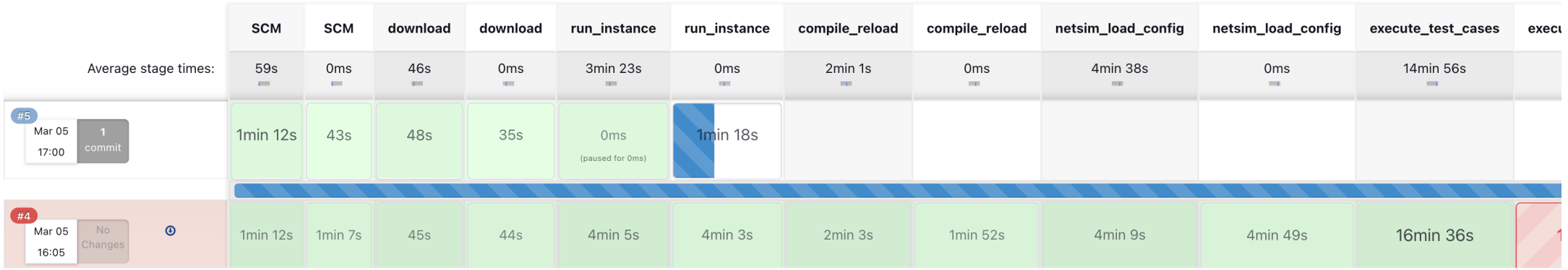
CICD Pipeline - Demo

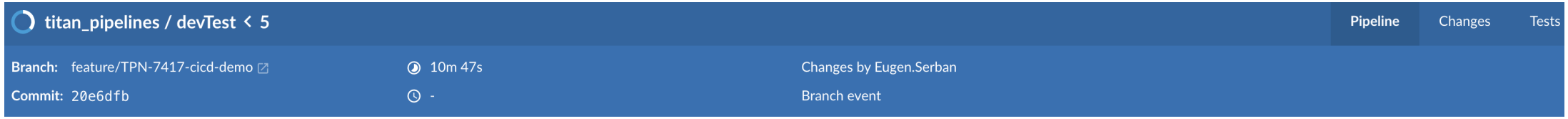
- New Branch feature/TPN-7417-cicd-demo is created on "titan_services" git repo
- New Jenkins job is created

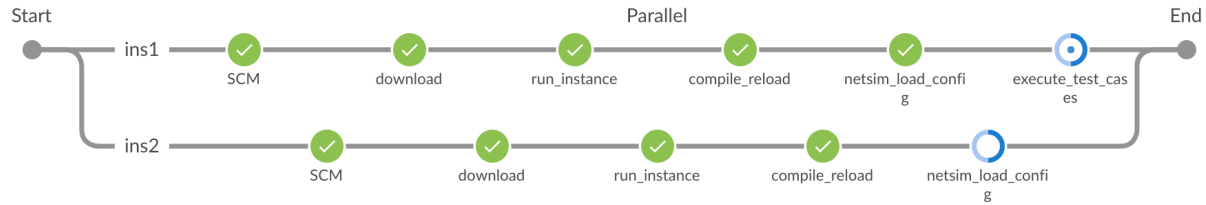
Pipeline feature/TPN-7417-cicd-demo

Full project name: titan_pipelines/devTest/feature%2FTPN-7417-cicd-demo

Stage View







Parallel / ins1 - 6m 26s

- rm -rf *;rm -rf .git* .scannerwork .vscode .env — Shell Script
- Check out from version control
- BranchName _____ and Branch url https://git.swisscom.com/scm/nso/titan_services.git — Print Message
- /var/data/workspace/vTest_feature_TPN-7417-cicd-demo/config/config.yaml — Read yaml from files in the workspace or text.
- dp=[nso-generic-local/ned-packages/cisco/iosxr/netconf/ncs-6.1.6-cisco-iosxr_netconf-7.8.2.1.tar.gz, nso-generic-local/ned-packages/cisco/iosxr/netconf/ncs-6.1.5-cisco-iosxr_netconf-7.7.21.1.tar.gz, nso-generic-local/ned-packages/cisco/iosxr/net

Resiliance tests in production

Daniel Müller, Lead SRE Network Connectivity
Bartlomiej Bacal, Network Engineer Titan

Reliability Enhancing Procedures (REP)

REP1
Model Your **Service Definition**

REP5
Introduce **Service Level Objectives**

REP2
Service **Availability Requirements** & **Reliability Design**

SMA
Service Management **Assessment**

REP6
Service Continuity & Disaster Recovery

REP4
Provide Service Specification & Usage Instruction

REP3
Service **Roasting**

REP8
Resilience **Testing in Production**

REP9
Operation **Response Testing**

REP8: Resilience Testing in Production

Key Benefits

1. Ensure the redundancy concepts work as designed
2. Discover additional points-of-failures
3. Trust your systems

Main Deliverables

- Up-to-date Documentation
- Extensive risks analysis
- Execution the resilience tests
- Problems identifications

Methodology

Step by step analyze, plan, and test the resilience of your service

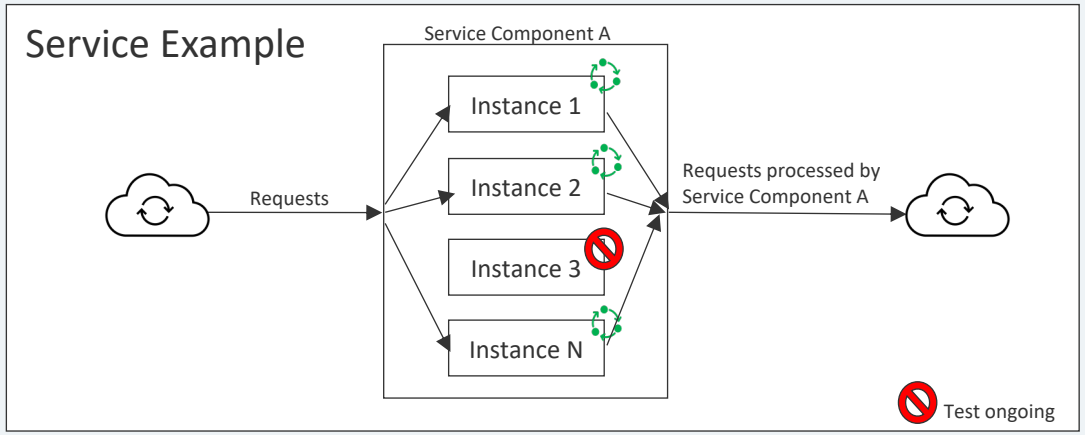
Phase 1 Readiness documentation

Phase 2 Resilience Analysis

Phase 3 Test cases definition

Phase 4 Resilience Testing

Phase 5 Continuous Improvements



Why Testing In Lab Or Preprod Is Not Enough?

Where Prod differs from Lab/Preprod – In a networking perspective

Network size, number of nodes

Workload

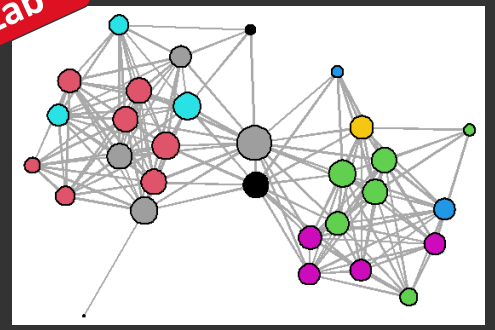
Number of prefixes

Size of routing table

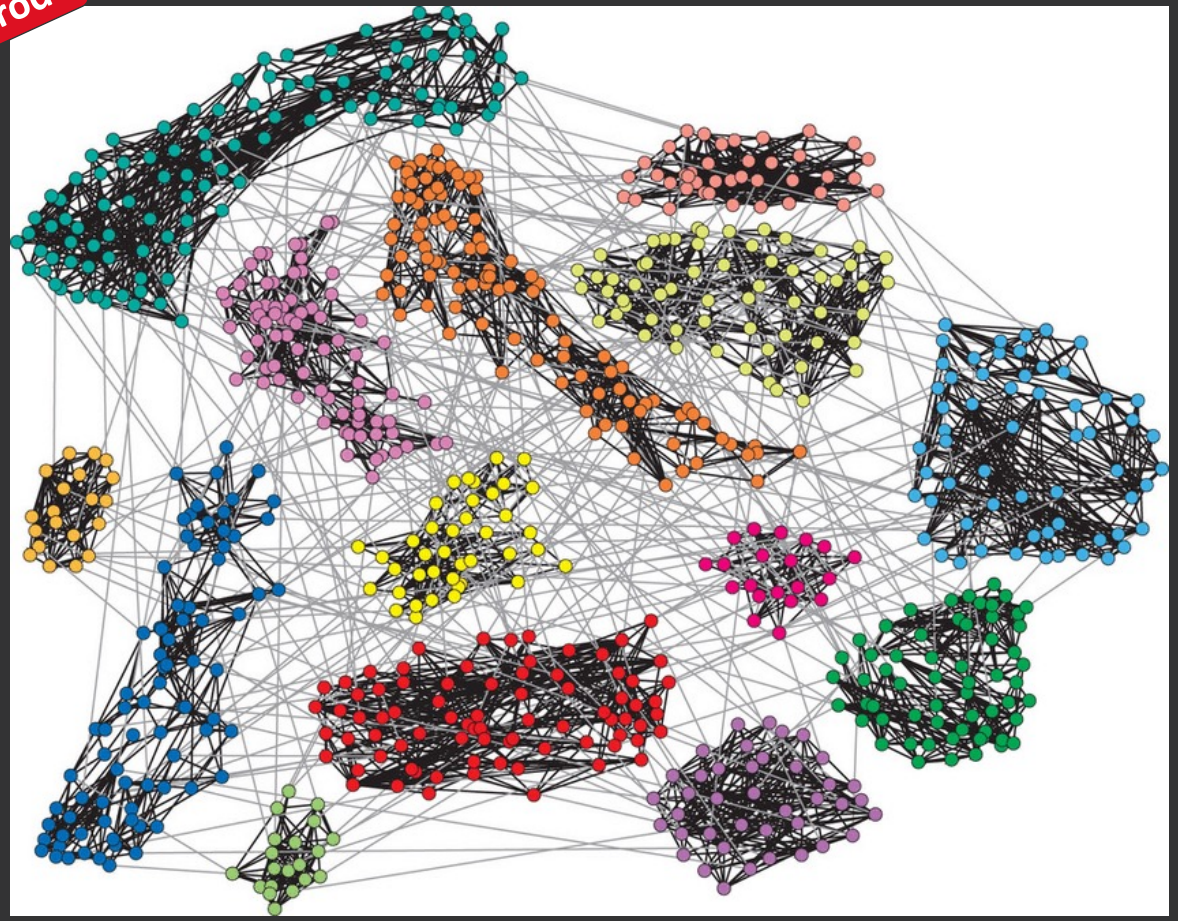
Dependencies

Latency

Lab



Prod



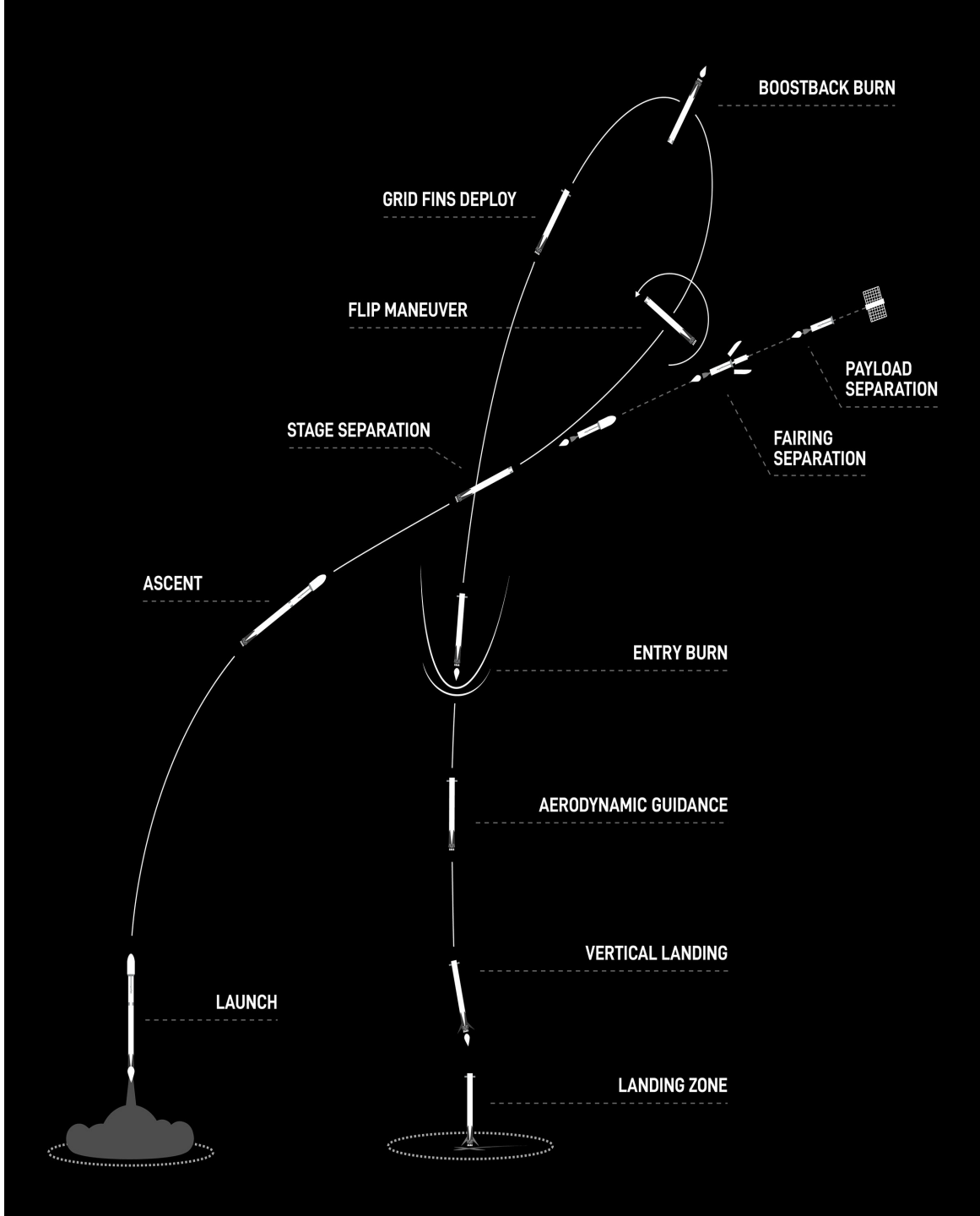
What We Do With REP8@TITAN

1. **Manual execution REP8**
   - Definition and planning of use cases
   - Manual execution without active customer services
   - First automations - Pre/Post check

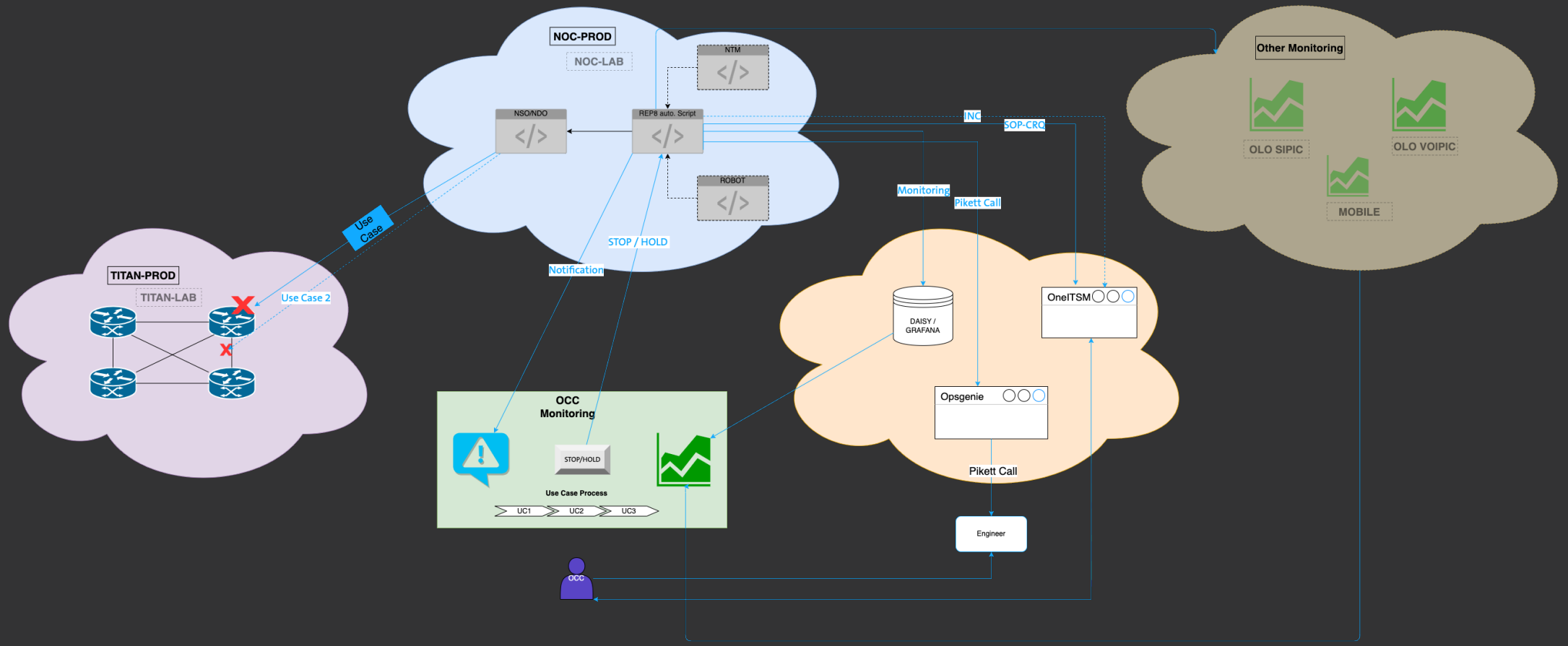
2. **Automation of use cases and pre/post check**
   - Full automated pre and post checks
   - Automated use case execution

3. **Process topics**
   - Status of the test visible for OCC
   - Change/Incident handling
   - Error handling (Engineer call-out etc.)
   - Definition of stop criteria and function

4. **Crazy Tuesday**
   - Regular, fully automated execution of REP8 on TITAN
   - Quality seal
   - Further improvements



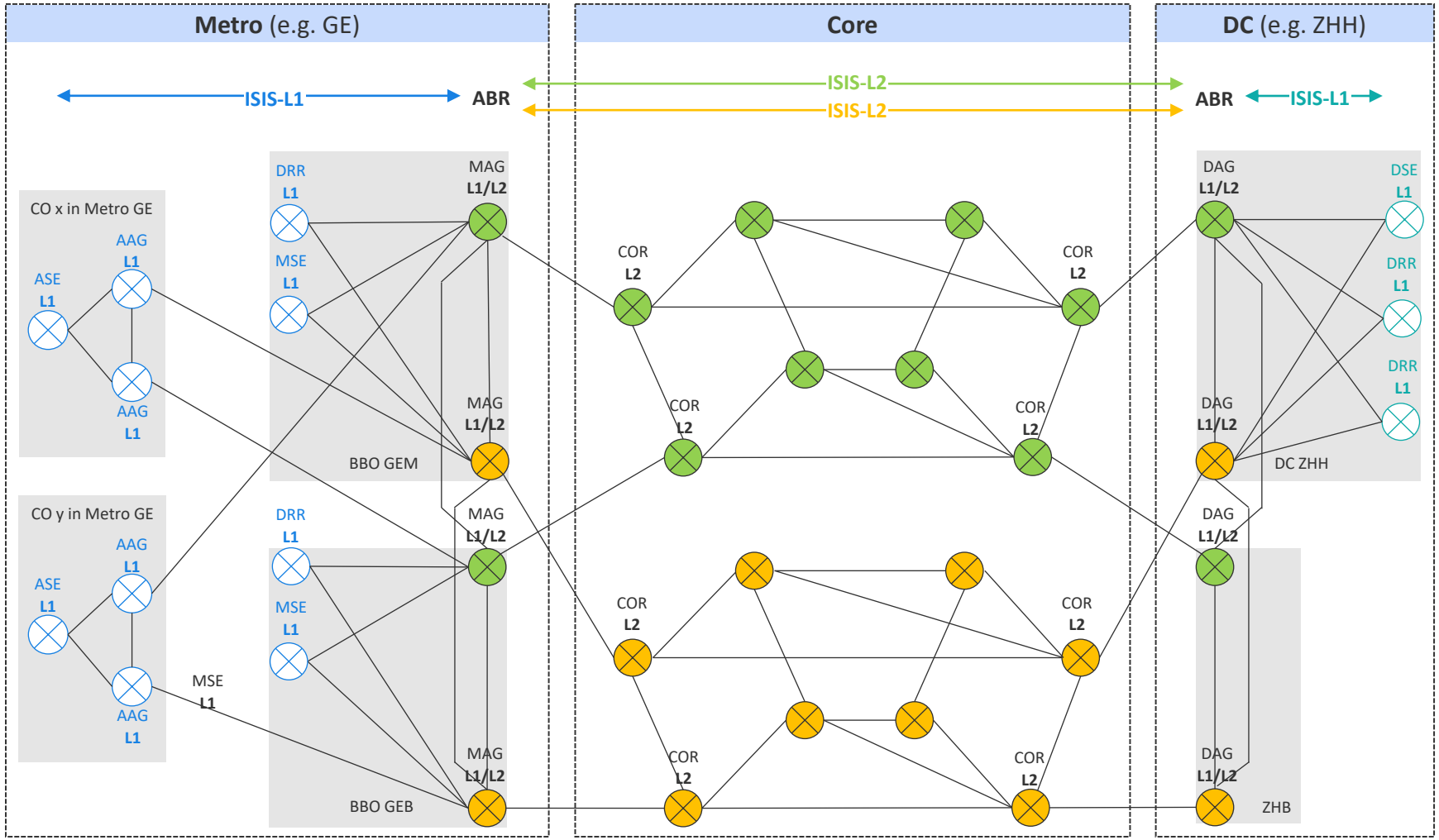
Target Solution Fully Automated REP8



Last Update: 14.09.2023, Rolf

IGP Concept (IS-IS for SRv6 with TI-LFA, FlexAlgo and UPA)

Metros and Datacenters are Level 1, each Core Plane is Level 2



IGP

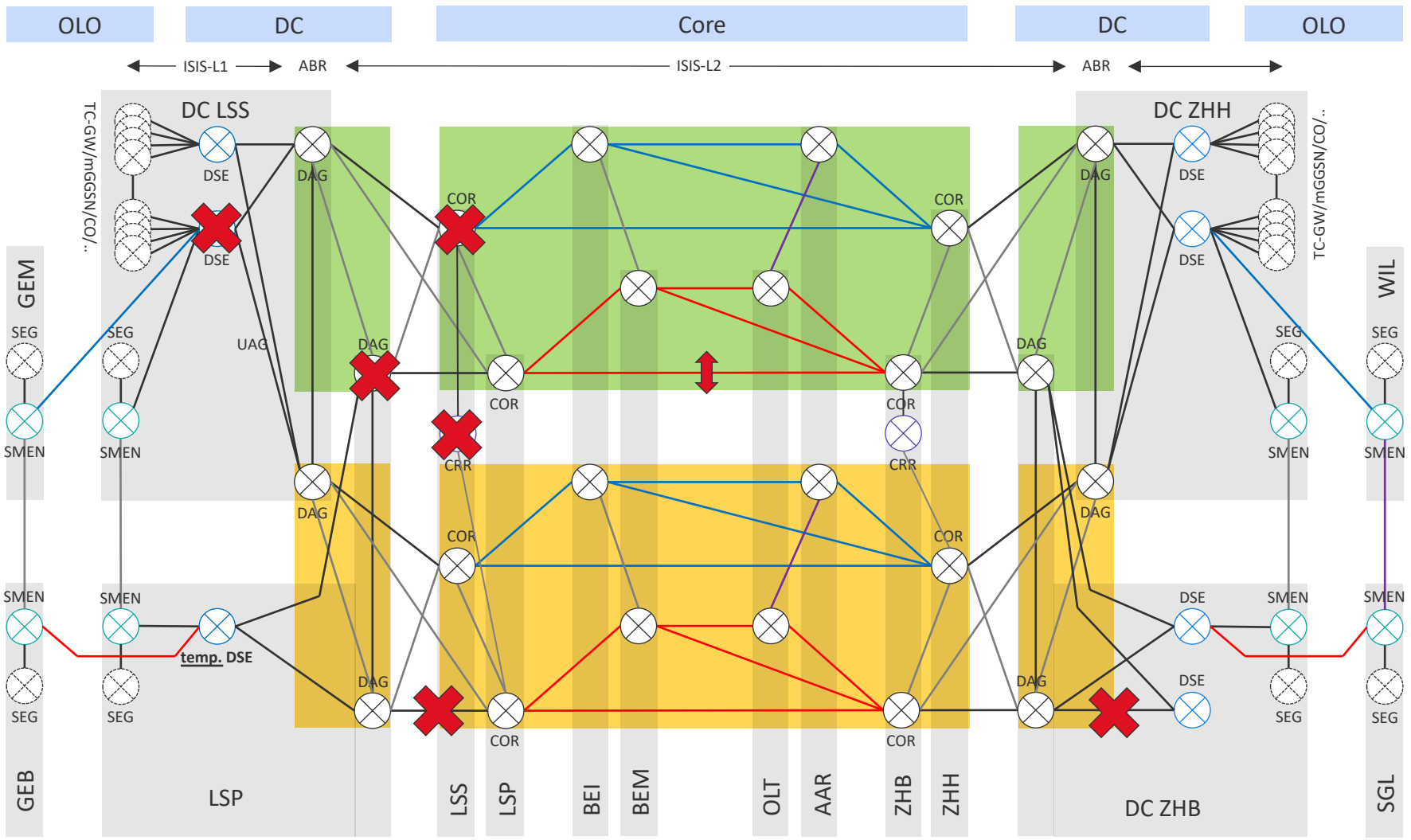
- IS-IS with SRv6/uSID extension
- TI-LFA based fast convergence for all single failure cases
  - this was the reason, why we introduced 4 DAG/MAG routers instead of 2 per Datacenter/Metro
- FlexAlgo to provide Low-Latency or Disjoint-Paths topologies
- UPA* on DAG/AAG to signal PE outages to remote Datacenters/Metros for PIC Edge based fast convergence

IS-IS Topology

- TITAN Core is IS-IS L2
  - IS-IS L2 for green Core Plane
  - IS-IS L2 for orange Core Plane
- TITAN Datacenter is IS-IS L1
- TITAN Metro is IS-IS L1
- DAG is ABR (IS-IS L1/L2)
  - summarizes locators of the DC with /40 aggregate(s) towards the Core
- MAG is ABR (IS-IS L1/L2)
  - summarizes locators of the Metro with /40 aggregate(s) towards the Core

*UPA = Unreachable Prefix Announcement, FCS with IOS-XR 7.8.1

REP8: TITAN Use Cases

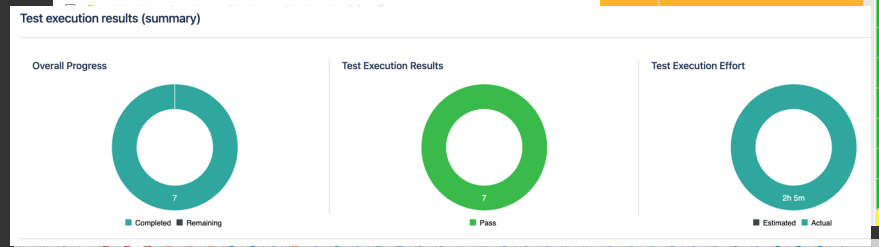


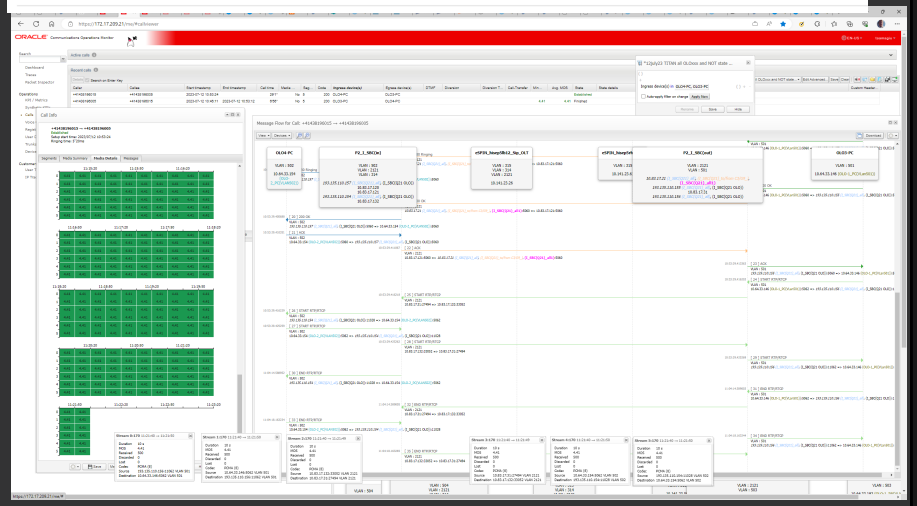
Results Of First Manual REP8 On TITAN

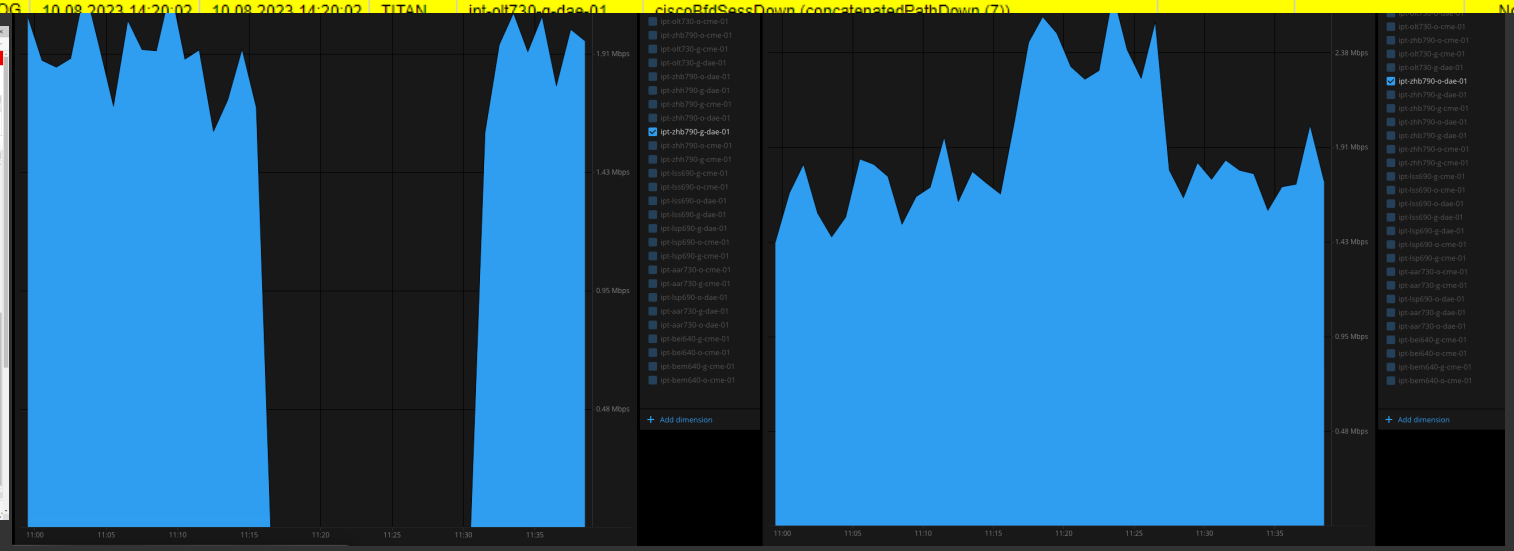
P	Key	V	Name
	NRE-T30	1.0	REP8-2.0: UC1 -- ZHB <-> DAG Node Failure
	NRE-T35	1.0	REP8-2.0: UC14 -- ZHB Core <-> Core Link Failure
	NRE-T36	1.0	REP8-2.0: UC15 -- ZHB BGP Process Crash on DSE
	NRE-T31	1.0	REP8-2.0: UC3 -- ZHB DAG <-> COR Link failure
	NRE-T32	1.0	REP8-2.0: UC4 -- ZHB CORE Node Failure
	NRE-T33	1.0	REP8-2.0: UC6 -- OLT DSE <-> DAG Link Failure
	NRE-T34	1.0	REP82.0: UC8 -- ZHB RR Node Failure
	NRE-T13	1.0	REP8: UC1-ZHH-DAG Node Failure
	NRE-T22	1.0	REP8: UC10-Process restart
	NRE-T23	1.0	REP8: UC11-RP failover (ASR9K)
	NRE-T25	1.0	REP8: UC13-ZHB MES --DAG Link Failure
	NRE-T27	1.0	REP8: UC14-ZHB Core -- Core Link Failure
	NRE-T29	1.0	REP8: UC15-ZHB BGP Process Crash on DSE
	NRE-T14	1.0	REP8: UC2-ZHH-DSE Node Failure
	NRE-T17	1.0	REP8: UC3-ZHH-DAG-COR Link Failure
	NRE-T15	1.0	REP8: UC4-ZHB-COR Node Failure

OC	LastOccurrence	CurrentSince	Netz	Node	Summary	SummaryAddo
BTR	10.08.2023 11:41:28	10.08.2023 11:41:28	TITAN	ipt-zhb790-g-cme-01	isisAdjacencyChange: A notification sent when an adjacency changes	
BTR	10.08.2023 11:41:28	10.08.2023 11:41:28	TITAN	ipt-zhb790-g-dae-01	isisAdjacencyChange: A notification sent when an adjacency changes	
LOG	10.08.2023 11:41:28	10.08.2023 11:41:28	TITAN	ipt-zhb790-g-cme-01	ciscoBfdSessDown (concatenatedPathDown (7))	
LOG	10.08.2023 11:41:28	10.08.2023 11:41:28	TITAN	ipt-zhb790-g-dae-01	ciscoBfdSessDown (concatenatedPathDown (7))	
BTR	10.08.2023 11:41:27	10.08.2023 11:41:27	TITAN	ipt-zhb790-g-cme-01	ISIS (TITAN): Adjacency to ipt-zhb790-g-dae-01 (Bundle-Ether2000)	
LOG	10.08.2023 11:41:27	10.08.2023 11:41:26	TITAN	ipt-zhb790-g-cme-01	Interface Bundle-Ether2000 changed state to down	
LOG	10.08.2023 11:41:27	10.08.2023 11:41:26	TITAN	ipt-zhb790-g-dae-01	Interface Bundle-Ether2000 changed state to down	
UEB	10.08.2023 11:41:26					
UEB	10.08.2023 11:41:26					

OC	LastOccurrence	CurrentSince	Netz	Node	Summary	SummaryAddo	Ticket	TicketStatus
BTR	10.08.2023 14:27:33	10.08.2023 14:27:33	TITAN	ipt-olt730-g-dae-01	isisAdjacencyChange: A notification sent when an adjacency changes			Not in ITSM
BTR	10.08.2023 14:27:33	10.08.2023 14:27:33	TITAN	ipt-olt730-g-dae-01	ISIS (TITAN): Adjacency to ipt-olt730-b-des-01 (Bundle-Ether4001) (L			Not in ITSM
BTR	10.08.2023 14:27:33	10.08.2023 14:27:33	TITAN	ipt-olt730-b-des-01	isisAdjacencyChange: A notification sent when an adjacency changes			Not in ITSM
BTR	10.08.2023 14:27:33	10.08.2023 14:27:33	TITAN	ipt-olt730-b-des-01	ISIS (TITAN): Adjacency to ipt-olt730-g-dae-01 (Bundle-Ether2000) (L			Not in ITSM
LOG	10.08.2023 14:27:26	10.08.2023 14:27:26	TITAN	ipt-olt730-g-dae-01	Interface Bundle-Ether4001 changed state to down			Not in ITSM
LOG	10.08.2023 14:27:26	10.08.2023 14:27:26	TITAN	ipt-olt730-b-des-01	Interface Bundle-Ether2000 changed state to down			Not in ITSM
UEB	10.08.2023 14:27:06	10.08.2023 14:27:06	TITAN	ipt-olt730-b-des-01	Edge-Edge: Interface FourHundredGigE0/0/1/4 changed state to dow			Not in ITSM
UEB	10.08.2023 14:27:06	10.08.2023 14:27:06	TITAN	ipt-olt730-g-dae-01	Edge-Edge: Interface FourHundredGigE0/0/0/30 changed state to do			Not in ITSM
LOG	10.08.2023 14:20:02	10.08.2023 14:20:02	TITAN	ipt-olt730-g-dae-01	ciscoBfdSessDown (concatenatedPathDown (7))			Not in ITSM



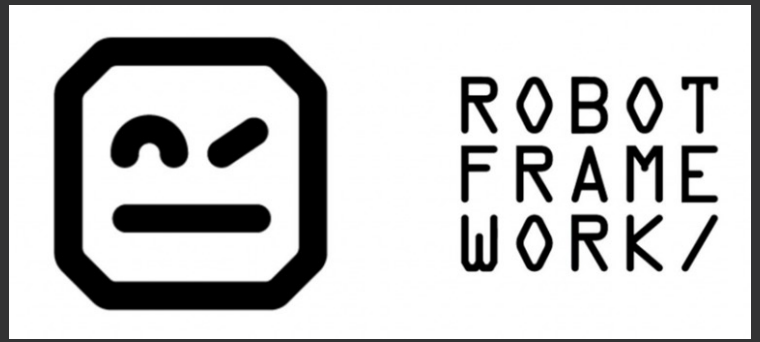




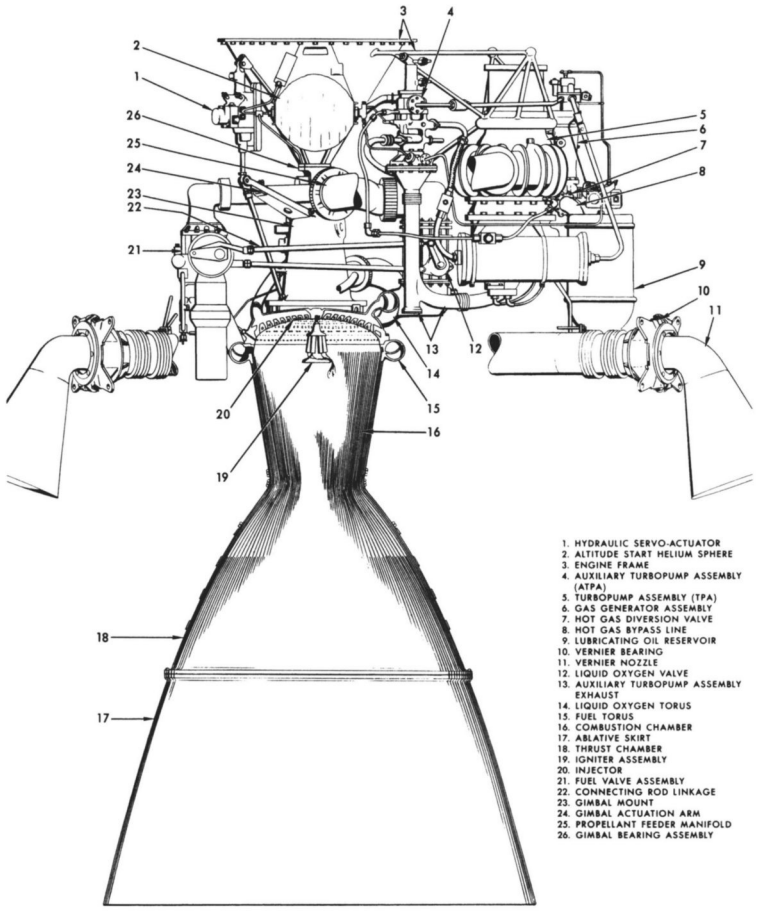
Solution Overview

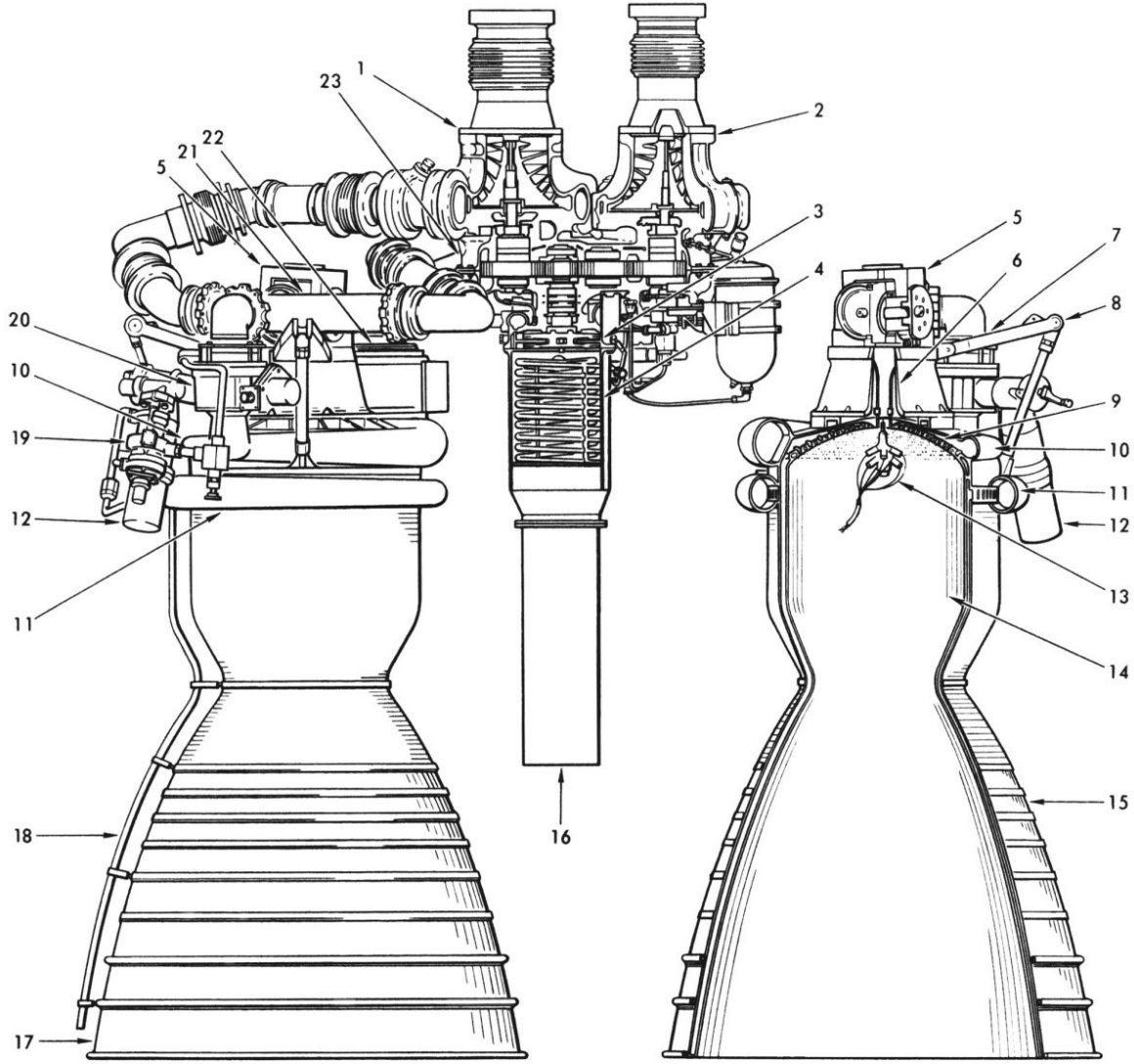
- Fundation Platform
  - Robot Framework and CX Test Automation Manager
  - pyATS and Genie

- Implementation
  - Baseline Test – developed and used in all TITAN stages
  - Pre-/Post-checks – developed for REP8 use cases



Questions And Answers





Source: www.enginehistory.org

Backup