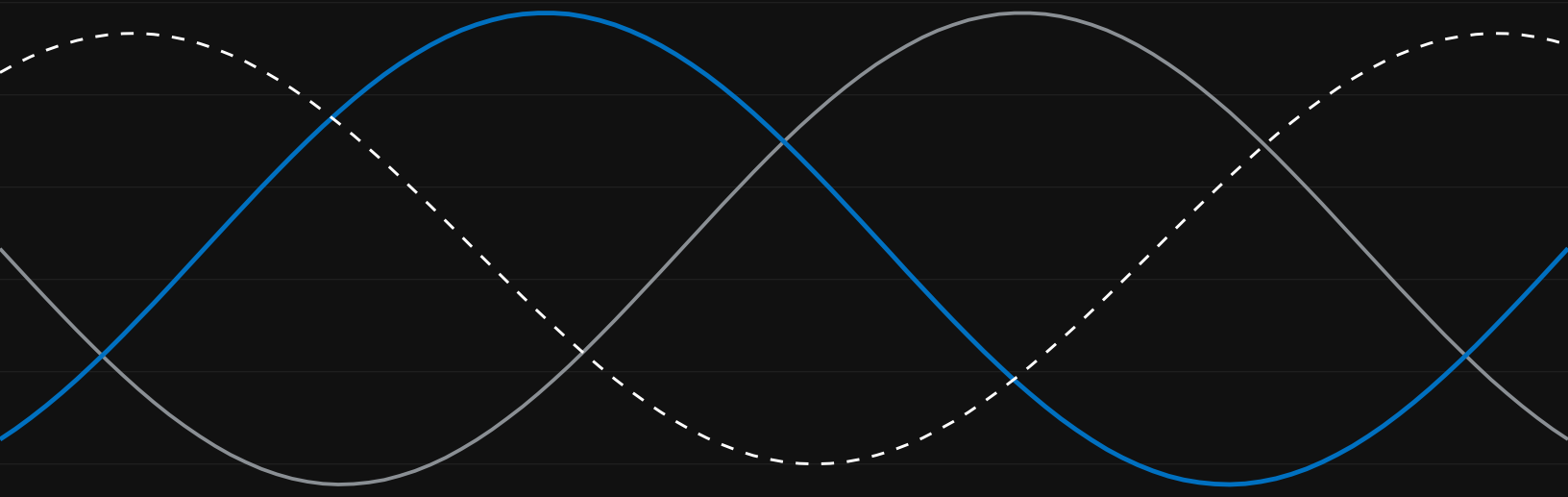
Worked example

Kestrel Orbital worked enumeration (ETEN reference workbook)

The ETEN process applied to one platform: 4 environments, 4 segments, 15 services and 21 assets, 44 elements, each with its record.



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Scope and standing of this work · read before judging the enumeration

What this is. Kestrel Orbital's first application of the METEORSTORM framework, produced by three departments who had never used it before. It is a deliberately scoped first pass over the telecommand path: the command-and-control chain from the operator console to execution on orbit. This workbook is the first product of that work, the Day-1 CONOPS.

Why that scope, and not more. The three mandates chose it. Executive Order 14144 sets the command-and-control protections required of civil space systems, which Kestrel Orbital adopts as binding by company directive, the NIS2 Directive places a duty of care and a reporting clock on the ground operator, and the Space ISAC exchange carries what the other two produce. The fleet is already flying, so the first pass ran on the telecommand path, the elements that would end the mission if an adversary took them. Enumerating everything else first would have been thorough and useless.

What it is not, stated plainly. It is not an exhaustive model of the platform and does not claim to be. Elements off the telecommand path are not enumerated. Some assets group several physical units where those units share an owner, a build and a patch path. Gaps in the ordinal sequence mark elements the register tracks outside this scope. Within the path the service and asset layers are a first pass, and a second pass would find more. Every one of those is a decision recorded when the enumeration was made, not an oversight discovered later.

How it grows. Ordinals are issued once and never renumbered, so everything enumerated here keeps its identifier as the register expands. The same eight-step enumeration procedure from Module 01 runs on the next scope, and the one after that. A first pass that names its boundary can be extended. One that hides its boundary has to be rebuilt.

The standard we hold ourselves to. A scope choice is stated openly. A defect is fixed, never narrated. If you find an element misnamed, a parent wrong, or a count that does not add up, that is a defect and we want to hear about it. If you find something outside the telecommand path missing, that is the scope, it was chosen deliberately, and it is on the roadmap. The two are not the same criticism, and this work is built so you can tell them apart.

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Use this at work

This workbook is a worked example. It follows one enumeration, Kestrel Orbital's first pass over its telecommand path, from the scope to 44 finished records. It is a pattern to copy from, not a form to fill in.

To enumerate your own platform, use two things together:

- **The METEORSTORM desk pack** (a separate download, meteorstorm-desk-pack.pdf): the quick reference with all 24 structural tags, the Function 01 method card, the blank element record sheet, the blank register sheet, and the checklist.
- **The ETEN process in this workbook**, on page 6: the eight steps and the four layer gates, with nothing in it that is specific to Kestrel.

What this workbook shows	Page
The eight steps and the four layer gates, written for any platform	6
How to read a record: the five ETEN fields, PARENT and REFERENCE	7
The acronyms the figures and the records use	8
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Services: the figure after step 3, recommendations and 15 finished records	18
Assets: 21 finished records, including an asset with more than one parent	25

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The ETEN process

The enumeration that produces every ETEN is governed by the normative process: the scope bounds what is enumerated, the taxonomy supplies the tag and label, the ontology links the parent, and the description states the instance.

Step 01	**Set the scope**, from the resilience objective and the requirements that drive the decomposition; an element outside the scope is not enumerated.
Step 02	**Select the layer**, working top down through the taxonomy's structural layers, and confirm the element passes that layer's definition gate before proceeding. The gates are the taxonomy's layer definitions, verbatim: **PCE** **Primary Capability Environment.** "Operational zone in which a capability primarily exists or is exercised." The gate: you are naming a WHERE, a zone, not a thing in it. **SEG** **Segment.** "Service and asset enclaves that compose the system across environments." The gate: you are naming an ENCLAVE, a grouping of services and assets, not the zone it sits in and not the hardware inside it. **SVC** **Service.** "Functional planes that organize control and data responsibilities." The gate: you are naming a functional RESPONSIBILITY, what the platform does, not what it is built from. **AST** **Asset.** "Asset classes composing the system and its interfaces." The gate: you are naming a CONCRETE ELEMENT, a real component the platform is built from. Tiebreak for the recurring trap: PCE and SEG carry similar element names (Orbital and Space, Aquatic, Deep Space) but are different things. Ask: am I naming a zone, or a group of services and assets? Zone means PCE; group means SEG. An element that fails its layer's gate is not enumerated at that layer; reclassify and re-enter at Step 02. Enrichment (AN) follows in Functions 02 through 05.
Step 03	**Select the tag** from the taxonomy for that layer; never invent one.
Step 04	**Write the label** for that tag exactly as the METEORSTORM normative reference prints it: the short form of the published name.
Step 05	**Assign the ordinal**, two digits from 00, counted per tag.
Step 06	**Link the parent** one layer up. This link is the ontology: every child names its parent, PCE is the root, and no element is an orphan. The parent chain enforces the layer gates structurally: a segment names one or more environments, a service names one or more segments, and an asset names one or more services, never zero. An analytic element takes no parent; it anchors through its target field.
Step 07	**Set the optional fields**: a service marks DISTRIBUTED when it spans more than one segment; an asset may carry a SUBSYSTEM grouping; an analytic element carries its TARGET and SOURCE.
Step 08	**Write the description**, one plain sentence stating what this exact instance is on this platform, at its own layer: a zone for an environment, an enclave of services and assets for a segment, a responsibility for a service, a concrete element for an asset. The layer gate from Step 02 applies again here: a segment description never describes the hardware inside the enclave; a service description begins "The service that …"; an asset description begins with its element class ("The physical …", "The embedded …", "The flight software …", "The stored …", "The transmitted …"). An instance described at the wrong layer is non-compliant.

The Kestrel first pass recorded neither DISTRIBUTED nor SUBSYSTEM, so the records in this workbook do not show them.

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The Kestrel Enumeration

An Enumerated Taxonomic Element Nomenclature (ETEN) names one real element on a platform, in five fields.

ETEN example

Layer	**PCE**
Tag	**TE**
Label	**Terrestrial**
Ordinal	**00**
Description	**The Reston, Virginia land site: the terrestrial zone of primary mission operations and the network operations center.**

Kestrel Orbital's Security Operations Center, Satellite Operations Center, and Satellite Design & Engineering made this enumeration together. The scope came first, under Function 01, Concept of Operations: the telecommand path, the command-and-control scope Executive Order 14144 and the NIS2 Directive hold Kestrel to.

One pass by three departments does not exhaust a platform, and this enumeration is not exhaustive. It is enough: 44 elements that demonstrate to management that the three departments decompose one platform against one taxonomy, one ontology, and one process. The Day-1 CONOPS is the result.

Collaboration between an organization's teams is vital: it is what lets the organization adopt the Resilient Cyber Operations framework in the way that works best for it. Adoption is also the essence of space collective defense: every organization that enumerates against the same taxonomy and ontology can exchange enrichment machine to machine, and each new adopter makes that exchange easier.

Kestrel's scope is the telecommand path. Every record carries REFERENCE. REFERENCE is not one of the five ETEN fields and the ETEN process does not set it: it is the source reference the Kestrel inventory holds for the element, the published standard or document cited for it.

Why two orbital environments but one space inventory: the teams enumerated **PCE:OR:Orbital:00** (GEO) and **PCE:OR:Orbital:01** (MEO) separately, because regime-specific enrichment (space weather, contact geometry, radiation) attaches at the environment layer. They ruled one Space segment with one shared set of services and assets across both regimes, sized to the current workload: the fleet flies as one commanded constellation through one telecommand path, and splitting every flight service per regime would have roughly doubled the space-segment inventory before anyone knew whether the split earned its keep. The plan of record is to track the SDA (space domain awareness) to measure how much operational activity is specific to MEO versus GEO, then use that evidence to build the longer-term plan for coordinating enumeration of the entire platform.

Where this ends. Figure 1, on page 9, is the complete first pass, all 44 elements. The register that follows it lists them one to a row.

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The layer chapters walk the enumeration in the order the process runs it, top down, so every parent exists before its child: first the environments (PCE), then the segments (SEG) that name them, then the services (SVC) inside each segment, then the assets (AST) that implement each service. Each chapter opens with the figure as it stands at the end of that step, so the decomposition is seen being built rather than presented finished.

> **A simulated first pass, not a finished product.** This example does not enumerate everything on the platform. It is a simulated first pass, run to demonstrate the ETEN process on the telecommand path, and it does not measure how effectively a team delivers a full, final decomposition. The ordinal gaps and the out-of-scope segments are recorded boundaries of this pass, not omissions.

Acronyms

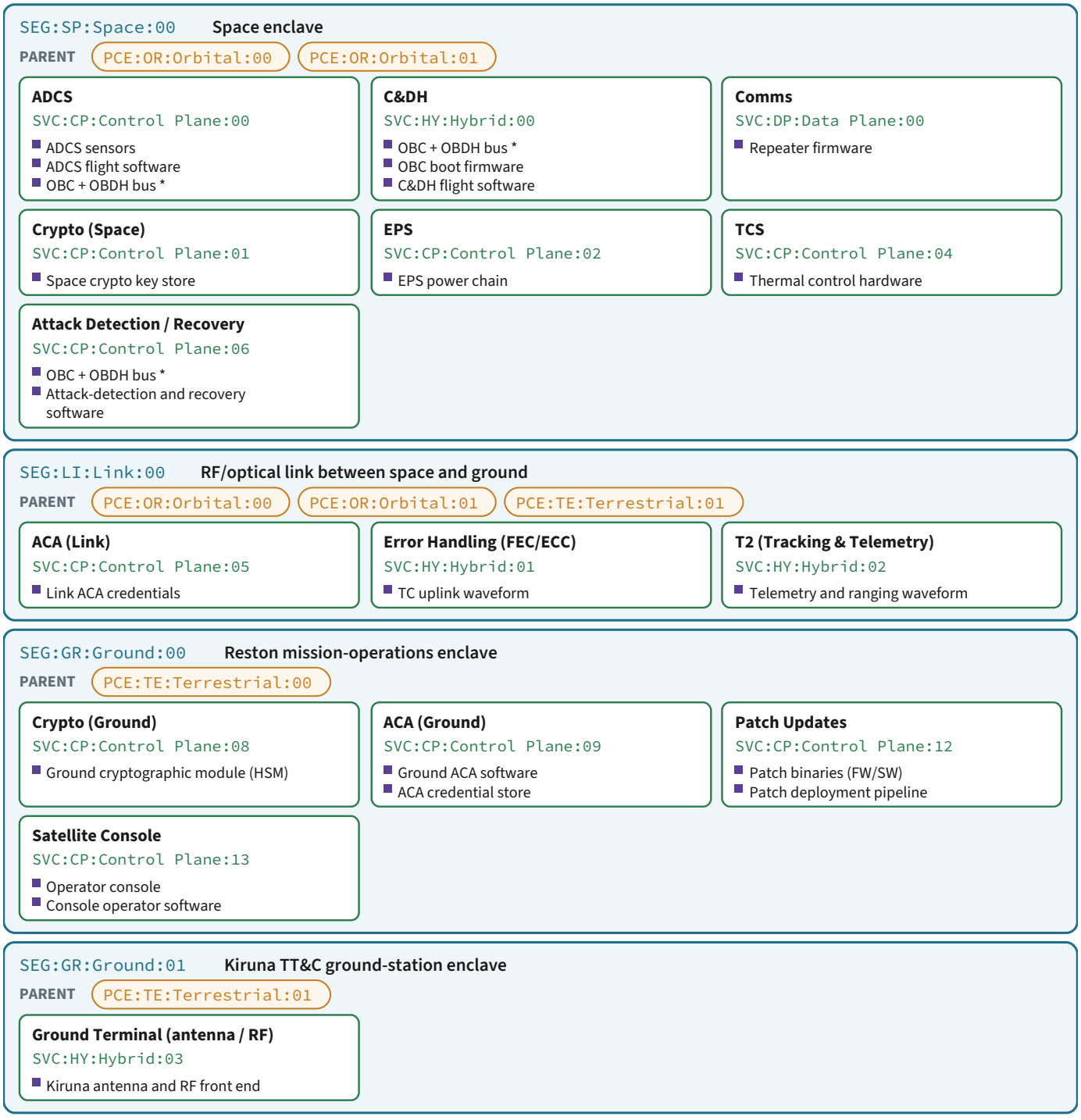
The acronyms the figures and the records use, spelled out once.

ADCS	Attitude Determination and Control System
ACA	Access Control and Authentication
C&DH	Command and Data Handling
EPS	Electrical Power System
TCS	Thermal Control System
OBC	On-Board Computer
OBDH	On-Board Data Handling
HSM	Hardware Security Module
FEC	Forward Error Correction
ECC	Error-Correcting Code
FDIR	Fault Detection, Isolation, and Recovery
TT&C	Telemetry, Tracking, and Command
T2	Tracking and Telemetry
NOC	Network Operations Center
RF	Radio Frequency
GEO	Geostationary Earth Orbit
MEO	Medium Earth Orbit
C2	Command and Control

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Kestrel Orbital Day-1 CONOPS, the telecommand path

Stage 4 of 4 · 44 of 44 elements · 4 PCE, 4 SEG, 15 SVC, 21 AST



Each band is one segment; its PARENT pills are the environments it names. * an asset that names more than one service is listed under each.

Figure 1. The Kestrel Orbital Day-1 CONOPS, the complete first pass over the telecommand path: 4 environments, 4 segments, 15 services and 21 assets, 44 elements. Each card in a band is one service, with the assets that implement it listed under it.

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Register of the enumerated elements

One row for each enumerated element: 4 environments, 4 segments, 15 services and 21 assets, 44 elements. The ETEN column is the identifier; the description on the element's record is joined to it to make the full ETEN. The name is the working name the figures use. A child with more than one parent lists each parent on its own line. Rows are in the order of the inventory.

ETEN	Name	Parent or parents
PCE Environment **4 environments**		
PCE:OR:Orbital:00	Geostationary orbit regime (GEO) the fleet flies in	none, root element
PCE:OR:Orbital:01	Medium Earth orbit regime (MEO) the fleet flies in	none, root element
PCE:TE:Terrestrial:00	Reston, Virginia mission-operations and NOC site	none, root element
PCE:TE:Terrestrial:01	Kiruna, Sweden TT&C ground-station site	none, root element
SEG Segment **4 segments**		
SEG:SP:Space:00	Space enclave	PCE:OR:Orbital:00 PCE:OR:Orbital:01
SEG:LI:Link:00	RF/optical link between space and ground	PCE:OR:Orbital:00 PCE:OR:Orbital:01 PCE:TE:Terrestrial:01
SEG:GR:Ground:00	Reston mission-operations enclave	PCE:TE:Terrestrial:00
SEG:GR:Ground:01	Kiruna TT&C ground-station enclave	PCE:TE:Terrestrial:01
SVC Service **15 services**		
SVC:CP:Control Plane:00	ADCS	SEG:SP:Space:00
SVC:HY:Hybrid:00	C&DH	SEG:SP:Space:00
SVC:DP:Data Plane:00	Comms	SEG:SP:Space:00
SVC:CP:Control Plane:01	Crypto (Space)	SEG:SP:Space:00
SVC:CP:Control Plane:02	EPS	SEG:SP:Space:00
SVC:CP:Control Plane:04	TCS	SEG:SP:Space:00
SVC:CP:Control Plane:05	ACA (Link)	SEG:LI:Link:00
SVC:HY:Hybrid:01	Error Handling (FEC/ECC)	SEG:LI:Link:00
SVC:CP:Control Plane:06	Attack Detection / Recovery	SEG:SP:Space:00
SVC:HY:Hybrid:02	T2 (Tracking & Telemetry)	SEG:LI:Link:00
SVC:CP:Control Plane:08	Crypto (Ground)	SEG:GR:Ground:00
SVC:CP:Control Plane:09	ACA (Ground)	SEG:GR:Ground:00
SVC:CP:Control Plane:12	Patch Updates	SEG:GR:Ground:00
SVC:CP:Control Plane:13	Satellite Console	SEG:GR:Ground:00
SVC:HY:Hybrid:03	Ground Terminal (antenna / RF)	SEG:GR:Ground:01

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ETEN	Name	Parent or parents
AST Asset **21 assets**		
AST:HW:Hardware:00	ADCS sensors	SVC:CP:Control Plane:00
AST:SW:Software:00	ADCS flight software	SVC:CP:Control Plane:00
AST:HW:Hardware:01	EPS power chain	SVC:CP:Control Plane:02
AST:HW:Hardware:03	Thermal control hardware	SVC:CP:Control Plane:04
AST:HW:Hardware:06	OBC + OBDH bus	SVC:HY:Hybrid:00 SVC:CP:Control Plane:00 SVC:CP:Control Plane:06
AST:FW:Firmware:01	OBC boot firmware	SVC:HY:Hybrid:00
AST:SW:Software:06	C&DH flight software	SVC:HY:Hybrid:00
AST:FW:Firmware:02	Repeater firmware	SVC:DP:Data Plane:00
AST:SI:Signal:00	TC uplink waveform	SVC:HY:Hybrid:01
AST:DA:Data:00	Link ACA credentials	SVC:CP:Control Plane:05
AST:SW:Software:02	Ground ACA software	SVC:CP:Control Plane:09
AST:DA:Data:01	ACA credential store	SVC:CP:Control Plane:09
AST:DA:Data:02	Patch binaries (FW/SW)	SVC:CP:Control Plane:12
AST:SW:Software:03	Patch deployment pipeline	SVC:CP:Control Plane:12
AST:HW:Hardware:04	Operator console	SVC:CP:Control Plane:13
AST:SW:Software:04	Console operator software	SVC:CP:Control Plane:13
AST:DA:Data:03	Space crypto key store	SVC:CP:Control Plane:01
AST:SW:Software:05	Attack-detection and recovery software	SVC:CP:Control Plane:06
AST:SI:Signal:01	Telemetry and ranging waveform	SVC:HY:Hybrid:02
AST:HW:Hardware:05	Ground cryptographic module (HSM)	SVC:CP:Control Plane:08
AST:HW:Hardware:08	Kiruna antenna and RF front end	SVC:HY:Hybrid:03

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L1 PCE · Environments (4)

Enumeration step 1 of 4 · PCE, the environments

01 PCE	02 SEG	03 SVC	04 AST

Step 1 names the four environments the telecommand path crosses: the two orbital regimes the fleet flies in, and the Reston and Kiruna sites. PCE is the root, so these elements name no parent. Everything below is still to be enumerated, and the dashed line counts it.

Kestrel Orbital Day-1 CONOPS, the telecommand path

Stage 1 of 4 · 4 of 44 elements · 4 PCE, 0 SEG, 0 SVC, 0 AST

PCE:OR:Orbital:00	PCE:OR:Orbital:01	PCE:TE:Terrestrial:00	PCE:TE:Terrestrial:01
Geostationary orbit regime (GEO) the fleet flies in	Medium Earth orbit regime (MEO) the fleet flies in	Reston, Virginia mission-operations and NOC site	Kiruna, Sweden TT&C ground-station site

4 segments, 15 services and 21 assets are enumerated at Stages 2 to 4, each naming its parent

PCE is the root layer: these four elements name no parent.

Figure 2. The enumeration after step 1 of 4: PCE, the environments.

PCE key points

Key point

What was missing: security frameworks carried no taxonomy and no ontology for the environment; where a platform operates was prose context, not an element that threats, detections, and resilience measures could anchor to.

Recommendation: enumerate every distinct operational zone as its own PCE, one per physical site; a new site is a new ordinal, no restructuring.

Kestrel: PCE:TE:Terrestrial:00 Reston, Virginia and **PCE:TE:Terrestrial:01** Kiruna, Sweden, so enrichment lands at the location level (terrestrial weather over the site, possible positioning of mobile electronic-warfare apparatus near it) while the set of environments preserves the global view.

Key point

What was missing: aerial, aquatic, orbital, and deep space were one undifferentiated environment, so there was no way to enrich by taxonomy and ontology for space domain awareness.

Recommendation: one PCE per orbital regime, never a generic orbital; the taxonomy already carries Terrestrial, Aquatic, Aerial, Orbital, and Deep Space, so the model extends without change.

Kestrel: the fleet spans two regimes, so it carries two orbital environments, **PCE:OR:Orbital:00** GEO and **PCE:OR:Orbital:01** MEO, aligning space-weather enumeration to each regime.

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Key point

What was missing: a rule for whether a fleet spanning two regimes needs its inventory split per regime or shared across them.

Recommendation: enumerate the environments separately, share one segment and one service and asset set while the workload supports it, and let evidence, not habit, decide a future split.

Kestrel: two orbital environments, one Space segment: one shared service and asset set sized to current workload; the teams track the SDA (space domain awareness) to measure what is MEO-specific versus GEO-specific, then build the longer-term plan to coordinate enumerating the entire platform.

PCE Environment

Geostationary orbit regime (GEO) the fleet flies in

PCE:OR:Orbital:00

ETEN nomenclature

PCE:OR:Orbital:00:The geostationary orbit regime (~35,786 km) part of the fleet flies in, fixing its coverage geometry, contact windows, and radiation exposure.

LAYER	**PCE** Primary Capability Environment (L1)
TAG	**OR**
LABEL	Orbital
ORDINAL	00
PARENT	none, root element
REFERENCE	METEORSTORM taxonomy (MISP, v2); NIST IR 8270
DESCRIPTION	The geostationary orbit regime (~35,786 km) part of the fleet flies in, fixing its coverage geometry, contact windows, and radiation exposure.

PCE Environment

Medium Earth orbit regime (MEO) the fleet flies in

PCE:OR:Orbital:01

ETEN nomenclature

PCE:OR:Orbital:01:The medium Earth orbit regime, where part of the fleet flies at ~8,000 km, with its own orbital periods, contact windows, and radiation environment.

LAYER	**PCE** Primary Capability Environment (L1)
TAG	**OR**
LABEL	Orbital
ORDINAL	01
PARENT	none, root element
REFERENCE	METEORSTORM taxonomy (MISP, v2); NIST IR 8270
DESCRIPTION	The medium Earth orbit regime, where part of the fleet flies at ~8,000 km, with its own orbital periods, contact windows, and radiation environment.

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PCE Environment

Reston, Virginia mission-operations and NOC site

PCE:TE:Terrestrial:00

ETEN nomenclature

> **PCE:TE:Terrestrial:00:The Reston, Virginia land site: the terrestrial zone of primary mission operations and the network operations center.**

LAYER	**PCE** Primary Capability Environment (L1)
TAG	**TE**
LABEL	Terrestrial
ORDINAL	00
PARENT	none, root element
REFERENCE	METEORSTORM taxonomy (MISP, v2); NIST IR 8401
DESCRIPTION	The Reston, Virginia land site: the terrestrial zone of primary mission operations and the network operations center.

PCE Environment

Kiruna, Sweden TT&C ground-station site

PCE:TE:Terrestrial:01

ETEN nomenclature

> **PCE:TE:Terrestrial:01:The Kiruna, Sweden land site (67.9°N): the terrestrial zone of the polar TT&C ground station that carries the command path into the link.**

LAYER	**PCE** Primary Capability Environment (L1)
TAG	**TE**
LABEL	Terrestrial
ORDINAL	01
PARENT	none, root element
REFERENCE	METEORSTORM taxonomy (MISP, v2); NIST IR 8401
DESCRIPTION	The Kiruna, Sweden land site (67.9°N): the terrestrial zone of the polar TT&C ground station that carries the command path into the link.

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L2 SEG · Segments (4)

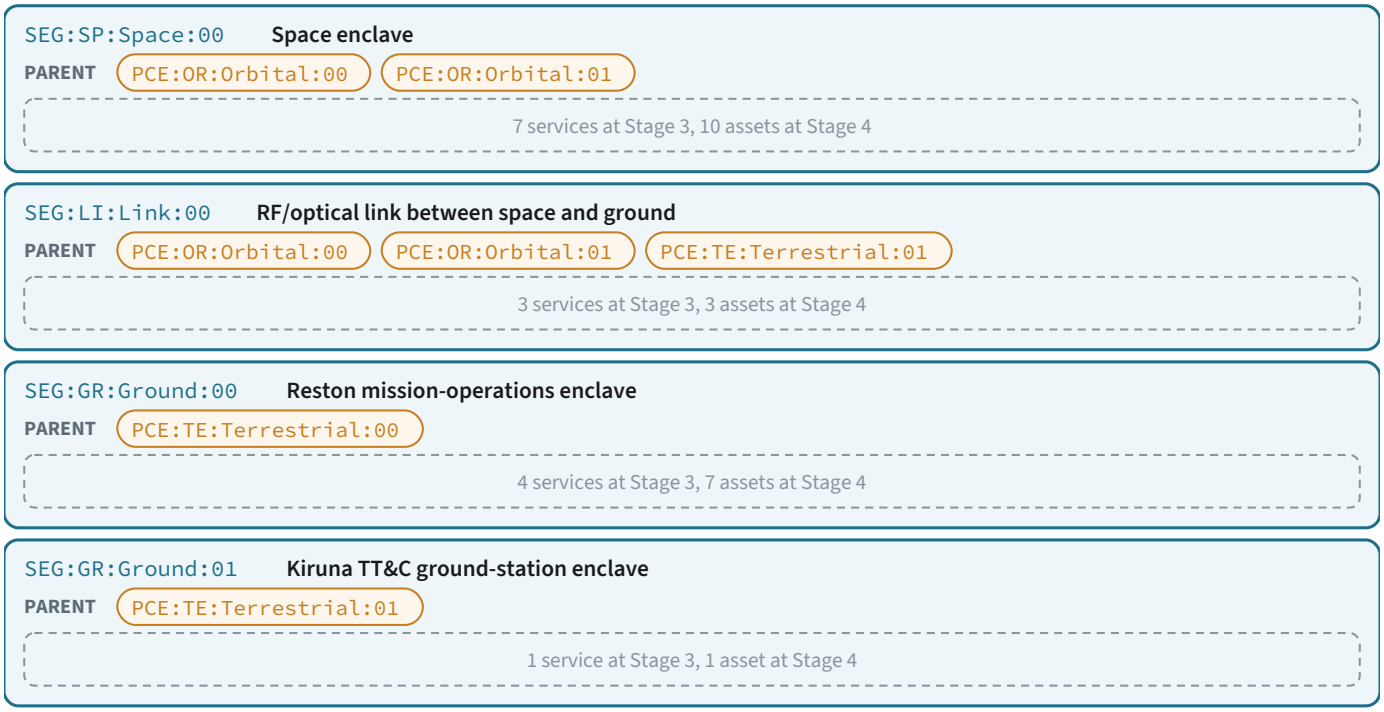
Enumeration step 2 of 4 · SEG, the segments

01 PCE	02 SEG	03 SVC	04 AST

Step 2 adds four segments, and each names its environments in PARENT. The Link segment names three, both orbital regimes and Kiruna, because the radio link runs from the Kiruna antenna to the fleet in both regimes.

Kestrel Orbital Day-1 CONOPS, the telecommand path

Stage 2 of 4 · 8 of 44 elements · 4 PCE, 4 SEG, 0 SVC, 0 AST



Each band is one segment; its PARENT pills are the environments it names.

Figure 3. The enumeration after step 2 of 4: SEG, the segments.

SEG key points

Key point

What was missing: enterprise models carried no enclave that spans environments, so jurisdiction and failover lived outside the model.

Recommendation: one segment per enclave of services and assets; each physically or jurisdictionally distinct enclave takes its own ordinal, and a cross-environment segment names every parent.

Kestrel: SEG:GR:Ground:00 Reston, Virginia under US authorities, **SEG:GR:Ground:01** Kiruna under Sweden and the EU, and the Link naming both the Orbital and Terrestrial environments.

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Key point

What was missing: models described the enterprise a company has today, so growth broke them.

Recommendation: the segment taxonomy already carries Launch, Link, Ground, User, Aquatic, Low Altitude, High Altitude, Near Space, Space, and Deep Space, so Resilient Cyber Operations is future proof by construction: a merger, an acquisition, or a new market enumerates into existing tags with new ordinals, never a remodel.

Kestrel: a downrange tracking ship enumerates as **SEG:AQ:Aquatic:00**, a stratospheric relay as **SEG:NE:Near Space:00**, and a mission beyond planetary orbital regimes as **SEG:DE:Deep Space:00**, the day the business needs them.

SEG Segment

Space enclave

SEG:SP:Space:00

ETEN nomenclature

> **SEG:SP:Space:00:The on-orbit enclave: the flight services and their assets operating on the constellation spacecraft, beyond physical reach.**

LAYER	**SEG** Segment (L2)
TAG	**SP**
LABEL	Space
ORDINAL	00
PARENT	PCE:OR:Orbital:00 + PCE:OR:Orbital:01
REFERENCE	NIST IR 8270
DESCRIPTION	The on-orbit enclave: the flight services and their assets operating on the constellation spacecraft, beyond physical reach.

SEG Segment

RF/optical link between space and ground

SEG:LI:Link:00

ETEN nomenclature

> **SEG:LI:Link:00:The link enclave: the services and assets carrying telecommand up and telemetry and mission data down across the RF and optical signal path between space and ground.**

LAYER	**SEG** Segment (L2)
TAG	**LI**
LABEL	Link
ORDINAL	00
PARENT	PCE:OR:Orbital:00 + PCE:OR:Orbital:01 + PCE:TE:Terrestrial:01
REFERENCE	NIST IR 8270; CCSDS 232.0-B
DESCRIPTION	The link enclave: the services and assets carrying telecommand up and telemetry and mission data down across the RF and optical signal path between space and ground.

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SEG Segment

Reston mission-operations enclave

SEG:GR:Ground:00

ETEN nomenclature

> **SEG:GR:Ground:00:The Reston, Virginia mission-operations enclave: the control, crypto, access-control, patch, and console services that command the constellation.**

LAYER	**SEG** Segment (L2)
TAG	**GR**
LABEL	Ground
ORDINAL	00
PARENT	PCE:TE:Terrestrial:00
REFERENCE	NIST IR 8270; NIST IR 8401
DESCRIPTION	The Reston, Virginia mission-operations enclave: the control, crypto, access-control, patch, and console services that command the constellation.

SEG Segment

Kiruna TT&C ground-station enclave

SEG:GR:Ground:01

ETEN nomenclature

> **SEG:GR:Ground:01:The Kiruna, Sweden polar TT&C ground-station enclave: the ground terminal service and its antenna and RF front end that radiate the command path into the link.**

LAYER	**SEG** Segment (L2)
TAG	**GR**
LABEL	Ground
ORDINAL	01
PARENT	PCE:TE:Terrestrial:01
REFERENCE	ESA/SSC Esrange-Kiruna documentation; NIST IR 8401
DESCRIPTION	The Kiruna, Sweden polar TT&C ground-station enclave: the ground terminal service and its antenna and RF front end that radiate the command path into the link.

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L3 SVC · Services (15)

Enumeration step 3 of 4 · SVC, the services

01 PCE	02 SEG	03 SVC	04 AST

Step 3 adds fifteen services, each naming its segment in PARENT: seven on the Space segment, three on the Link, four at Reston and one at Kiruna. Their assets are counted but not yet enumerated. An asset that names more than one service in PARENT is counted on each of those cards: AST:HW:Hardware:06 (OBC + OBDH bus) names 3. So the cards sum to 23 while this pass enumerates 21 assets. Figure 4 is on the next page.

SVC key points

Key point

What was missing: no plane-level taxonomy: command and mission traffic blurred together, and a cross-segment service was recorded under one segment, hiding the surface an adversary crosses.

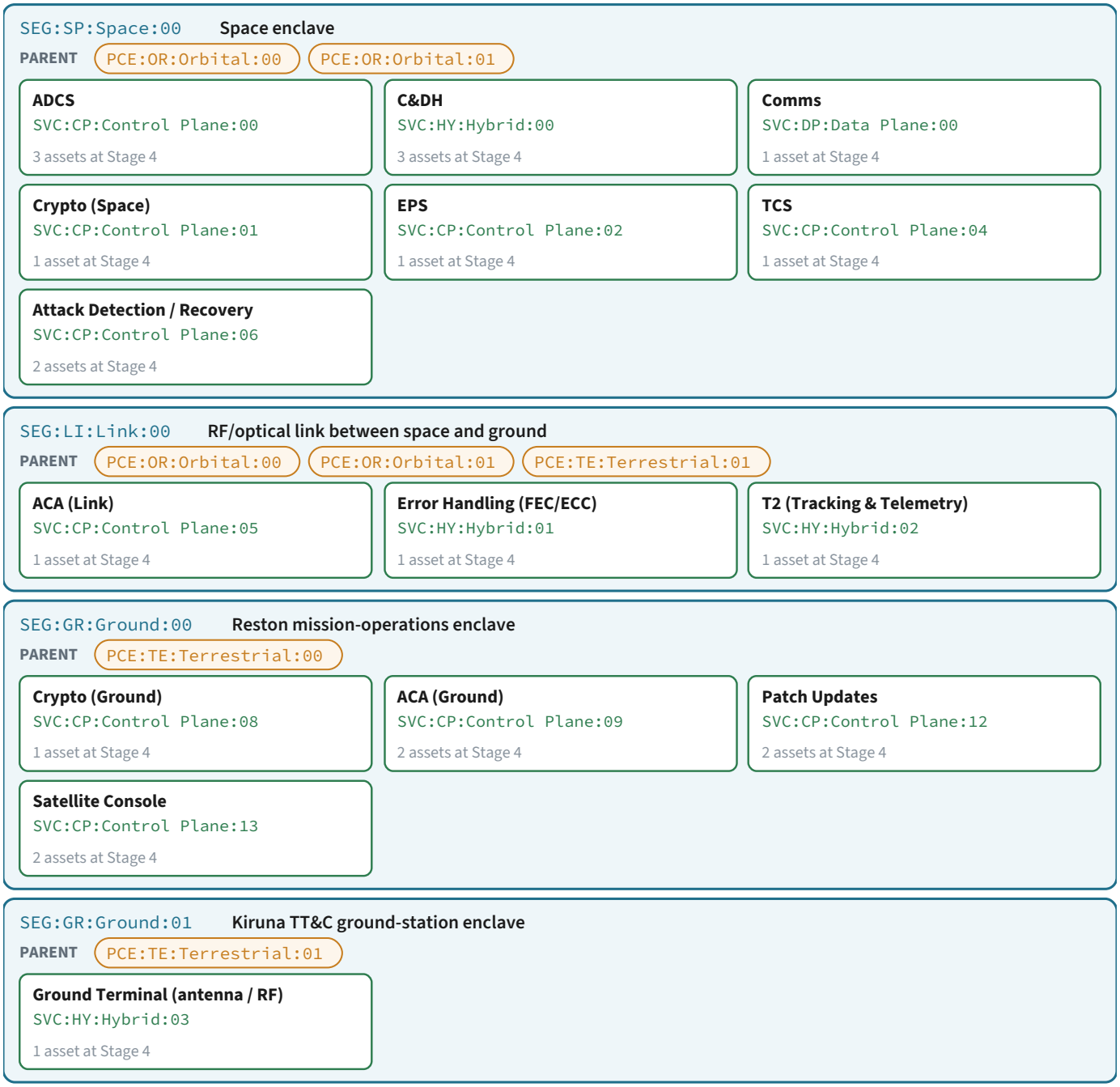
Recommendation: classify every service by what actually flows through it, Control Plane, Data Plane, or Hybrid when both, and mark DISTRIBUTED with every parent segment named.

Kestrel: SVC:HY:Hybrid:00 C&DH carries commands and mission data, so it is Hybrid by classification, not by guess.

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Kestrel Orbital Day-1 CONOPS, the telecommand path

Stage 3 of 4 · 23 of 44 elements · 4 PCE, 4 SEG, 15 SVC, 0 AST



Each band is one segment; its PARENT pills are the environments it names.

Figure 4. The enumeration after step 3 of 4: SVC, the services.

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Space segment services · parent SEG:SP:Space:00

SVC Service **ADCS** **SVC:CP:Control Plane:00**

ETEN nomenclature

> **SVC:CP:Control Plane:00:The service that determines and controls spacecraft orientation (ADCS).**

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	00
PARENT	SEG:SP:Space:00
REFERENCE	NASA/ESA ADCS
DESCRIPTION	The service that determines and controls spacecraft orientation (ADCS).

SVC Service **C&DH** **SVC:HY:Hybrid:00**

ETEN nomenclature

> **SVC:HY:Hybrid:00:The service that executes commands and moves data across the vehicle, on both the control and data planes (C&DH).**

LAYER	**SVC** Service (L3)
TAG	**HY**
LABEL	Hybrid
ORDINAL	00
PARENT	SEG:SP:Space:00
REFERENCE	ESA OBDH
DESCRIPTION	The service that executes commands and moves data across the vehicle, on both the control and data planes (C&DH).

SVC Service **Comms** **SVC:DP:Data Plane:00**

ETEN nomenclature

> **SVC:DP:Data Plane:00:The service that carries telemetry to the ground (Comms).**

LAYER	**SVC** Service (L3)
TAG	**DP**
LABEL	Data Plane
ORDINAL	00
PARENT	SEG:SP:Space:00
REFERENCE	CCSDS 132.0-B; NIST IR 8270
DESCRIPTION	The service that carries telemetry to the ground (Comms).

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SVC Service **Crypto (Space)** **SVC:CP:Control Plane:01**

ETEN nomenclature

> **SVC:CP:Control Plane:01:The service that encrypts and authenticates on board, including telecommand authentication (Crypto, space).**

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	01
PARENT	SEG:SP:Space:00
REFERENCE	NIST SP 800-57; Falco et al. 2024
DESCRIPTION	The service that encrypts and authenticates on board, including telecommand authentication (Crypto, space).

SVC Service **EPS** **SVC:CP:Control Plane:02**

ETEN nomenclature

> **SVC:CP:Control Plane:02:The service that generates, stores, and distributes electrical power (EPS).**

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	02
PARENT	SEG:SP:Space:00
REFERENCE	NASA SST (Power)
DESCRIPTION	The service that generates, stores, and distributes electrical power (EPS).

SVC Service **TCS** **SVC:CP:Control Plane:04**

ETEN nomenclature

> **SVC:CP:Control Plane:04:The service that holds every component within its temperature limits (TCS).**

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	04
PARENT	SEG:SP:Space:00
REFERENCE	NASA SST (Thermal)
DESCRIPTION	The service that holds every component within its temperature limits (TCS).

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SVC Service **Attack Detection / Recovery** **SVC:CP:Control Plane:06**

ETEN nomenclature

SVC:CP:Control Plane:06:The service that detects hostile command or state manipulation on board and recovers from it.

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	06
PARENT	SEG:SP:Space:00
REFERENCE	NIST IR 8270; Falco et al. 2024
DESCRIPTION	The service that detects hostile command or state manipulation on board and recovers from it.

Link segment services · parent SEG:LI:Link:00

SVC Service **ACA (Link)** **SVC:CP:Control Plane:05**

ETEN nomenclature

SVC:CP:Control Plane:05:The service that authenticates command sources and enforces command acceptance on the uplink (ACA, link).

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	05
PARENT	SEG:LI:Link:00
REFERENCE	Falco et al. 2024; NIST SP 800-57
DESCRIPTION	The service that authenticates command sources and enforces command acceptance on the uplink (ACA, link).

SVC Service **Error Handling (FEC/ECC)** **SVC:HY:Hybrid:01**

ETEN nomenclature

SVC:HY:Hybrid:01:The service that detects or corrects bit errors on the link (FEC/ECC error handling).

LAYER	**SVC** Service (L3)
TAG	**HY**
LABEL	Hybrid
ORDINAL	01
PARENT	SEG:LI:Link:00
REFERENCE	CCSDS 231.0-B
DESCRIPTION	The service that detects or corrects bit errors on the link (FEC/ECC error handling).

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SVC Service **T2 (Tracking & Telemetry)** **SVC:HY:Hybrid:02**

ETEN nomenclature

SVC:HY:Hybrid:02:The service that tracks the vehicle and returns telemetry across the control loop and the data path (T2).

LAYER	**SVC** Service (L3)
TAG	**HY**
LABEL	Hybrid
ORDINAL	02
PARENT	SEG:LI:Link:00
REFERENCE	CCSDS TT&C
DESCRIPTION	The service that tracks the vehicle and returns telemetry across the control loop and the data path (T2).

Ground segment services (Reston) · parent SEG:GR:Ground:00

SVC Service **Crypto (Ground)** **SVC:CP:Control Plane:08**

ETEN nomenclature

SVC:CP:Control Plane:08:The service that protects commands before uplink and data after downlink (Crypto, ground).

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	08
PARENT	SEG:GR:Ground:00
REFERENCE	NIST SP 800-57
DESCRIPTION	The service that protects commands before uplink and data after downlink (Crypto, ground).

SVC Service **ACA (Ground)** **SVC:CP:Control Plane:09**

ETEN nomenclature

SVC:CP:Control Plane:09:The service that decides who may command and which commands are released to the link (ACA, ground).

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	09
PARENT	SEG:GR:Ground:00
REFERENCE	Falco et al. 2024; NIST SP 800-57
DESCRIPTION	The service that decides who may command and which commands are released to the link (ACA, ground).

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SVC Service **Patch Updates** **SVC:CP:Control Plane:12**

ETEN nomenclature

> **SVC:CP:Control Plane:12:The service that delivers and installs software and firmware updates under control (Patch Updates).**

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	12
PARENT	SEG:GR:Ground:00
REFERENCE	NIST SP 800-40
DESCRIPTION	The service that delivers and installs software and firmware updates under control (Patch Updates).

SVC Service **Satellite Console** **SVC:CP:Control Plane:13**

ETEN nomenclature

> **SVC:CP:Control Plane:13:The service that gives operators the mission-ops console: telemetry monitoring and command issue.**

LAYER	**SVC** Service (L3)
TAG	**CP**
LABEL	Control Plane
ORDINAL	13
PARENT	SEG:GR:Ground:00
REFERENCE	NIST IR 8401
DESCRIPTION	The service that gives operators the mission-ops console: telemetry monitoring and command issue.

Ground segment services (Kiruna) · parent SEG:GR:Ground:01

SVC Service **Ground Terminal (antenna / RF)** **SVC:HY:Hybrid:03**

ETEN nomenclature

> **SVC:HY:Hybrid:03:The service that transmits the command uplink and receives the downlink at the Kiruna ground station (RF ground terminal).**

LAYER	**SVC** Service (L3)
TAG	**HY**
LABEL	Hybrid
ORDINAL	03
PARENT	SEG:GR:Ground:01
REFERENCE	NIST IR 8401; CCSDS TT&C
DESCRIPTION	The service that transmits the command uplink and receives the downlink at the Kiruna ground station (RF ground terminal).

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L4 AST · Assets (21)

Enumeration step 4 of 4 · AST, the assets

01 PCE	02 SEG	03 SVC	04 AST

Step 4 adds twenty-one assets, each naming the service or services it implements. Every enumerated element now resolves to an environment through the parent chain, and the first pass is complete. The figure at this step is the complete figure: Figure 1, on page 9.

AST key points

Key point

What was missing: asset inventories stopped at "the satellite" or "the ground system," and a bundle cannot carry a threat anchor.

Recommendation: one asset per concrete element under every service it physically carries, one or more, never zero, split to the depth you defend; a new asset slots under its service without renumbering.

Kestrel: AST:SI:Signal:00 the TC uplink waveform, **AST:DA:Data:03** the on-board key store, and **AST:FW:Firmware:01** the OBC boot firmware are separate elements, so a threat anchors to the exact asset it exploits, never a bundle.

Space segment assets · each parents to a service within SEG:SP:Space:00

AST Asset **ADCS sensors** **AST:HW:Hardware:00**

ETEN nomenclature

AST:HW:Hardware:00:The physical attitude sensors: star trackers, sun sensors, gyros, magnetometers.

LAYER	**AST** Asset (L4)
TAG	**HW**
LABEL	Hardware
ORDINAL	00
PARENT	SVC:CP:Control Plane:00
REFERENCE	NASA/ESA ADCS
DESCRIPTION	The physical attitude sensors: star trackers, sun sensors, gyros, magnetometers.

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AST Asset **ADCS flight software** **AST:SW:Software:00**

ETEN nomenclature

AST:SW:Software:00:The flight software that runs the ADCS control algorithms.

LAYER	**AST** Asset (L4)
TAG	**SW**
LABEL	Software
ORDINAL	00
PARENT	SVC:CP:Control Plane:00
REFERENCE	NASA cFS
DESCRIPTION	The flight software that runs the ADCS control algorithms.

AST Asset **EPS power chain** **AST:HW:Hardware:01**

ETEN nomenclature

AST:HW:Hardware:01:The physical power chain: solar arrays, batteries, power distribution.

LAYER	**AST** Asset (L4)
TAG	**HW**
LABEL	Hardware
ORDINAL	01
PARENT	SVC:CP:Control Plane:02
REFERENCE	NASA SST (Power)
DESCRIPTION	The physical power chain: solar arrays, batteries, power distribution.

AST Asset **Thermal control hardware** **AST:HW:Hardware:03**

ETEN nomenclature

AST:HW:Hardware:03:The physical thermal hardware: heaters, radiators, coatings, insulation.

LAYER	**AST** Asset (L4)
TAG	**HW**
LABEL	Hardware
ORDINAL	03
PARENT	SVC:CP:Control Plane:04
REFERENCE	NASA SST (Thermal)
DESCRIPTION	The physical thermal hardware: heaters, radiators, coatings, insulation.

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AST Asset **OBC + OBDH bus** **AST:HW:Hardware:06**

ETEN nomenclature

AST:HW:Hardware:06:The physical on-board computer and OBDH bus on each constellation spacecraft.

LAYER	**AST** Asset (L4)
TAG	**HW**
LABEL	Hardware
ORDINAL	06
PARENT	SVC:HY:Hybrid:00 + SVC:CP:Control Plane:00 + SVC:CP:Control Plane:06
REFERENCE	ESA OBDH
DESCRIPTION	The physical on-board computer and OBDH bus on each constellation spacecraft.

AST Asset **OBC boot firmware** **AST:FW:Firmware:01**

ETEN nomenclature

AST:FW:Firmware:01:The embedded OBC boot firmware, the root of trust that runs first at power-on.

LAYER	**AST** Asset (L4)
TAG	**FW**
LABEL	Firmware
ORDINAL	01
PARENT	SVC:HY:Hybrid:00
REFERENCE	NIST SP 800-193
DESCRIPTION	The embedded OBC boot firmware, the root of trust that runs first at power-on.

AST Asset **C&DH flight software** **AST:SW:Software:06**

ETEN nomenclature

AST:SW:Software:06:The flight software that executes commands and runs FDIR for C&DH.

LAYER	**AST** Asset (L4)
TAG	**SW**
LABEL	Software
ORDINAL	06
PARENT	SVC:HY:Hybrid:00
REFERENCE	NASA cFS; ESA OBDH
DESCRIPTION	The flight software that executes commands and runs FDIR for C&DH.

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AST Asset **Repeater firmware** **AST:FW:Firmware:02**

ETEN nomenclature

AST:FW:Firmware:02:The embedded repeater firmware that governs receive, process, and retransmit on the link.

LAYER	**AST** Asset (L4)
TAG	**FW**
LABEL	Firmware
ORDINAL	02
PARENT	SVC:DP:Data Plane:00
REFERENCE	NIST SP 800-193; CCSDS 232.0-B
DESCRIPTION	The embedded repeater firmware that governs receive, process, and retransmit on the link.

AST Asset **Space crypto key store** **AST:DA:Data:03**

ETEN nomenclature

AST:DA:Data:03:The stored flight keys and certificates the space cryptographic service encrypts and authenticates with.

LAYER	**AST** Asset (L4)
TAG	**DA**
LABEL	Data
ORDINAL	03
PARENT	SVC:CP:Control Plane:01
REFERENCE	CCSDS 355.0-B (SDLS); CCSDS 357.0-B; NIST SP 800-57
DESCRIPTION	The stored flight keys and certificates the space cryptographic service encrypts and authenticates with.

AST Asset **Attack-detection and recovery software** **AST:SW:Software:05**

ETEN nomenclature

AST:SW:Software:05:The flight software that detects hostile command or state manipulation in flight and recovers.

LAYER	**AST** Asset (L4)
TAG	**SW**
LABEL	Software
ORDINAL	05
PARENT	SVC:CP:Control Plane:06
REFERENCE	NIST IR 8270; Falco et al. 2024
DESCRIPTION	The flight software that detects hostile command or state manipulation in flight and recovers.

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Link segment assets · each parents to a service within SEG:LI:Link:00

AST Asset TC uplink waveform AST:SI:Signal:00

ETEN nomenclature

> **AST:SI:Signal:00:The transmitted telecommand uplink waveform that carries commands from ground to spacecraft.**

LAYER	**AST** Asset (L4)
TAG	**SI**
LABEL	Signal
ORDINAL	00
PARENT	SVC:HY:Hybrid:01
REFERENCE	CCSDS 231.0-B; CCSDS 232.0-B
DESCRIPTION	The transmitted telecommand uplink waveform that carries commands from ground to spacecraft.

AST Asset Link ACA credentials AST:DA:Data:00

ETEN nomenclature

> **AST:DA:Data:00:The stored link ACA credentials the access-control service checks.**

LAYER	**AST** Asset (L4)
TAG	**DA**
LABEL	Data
ORDINAL	00
PARENT	SVC:CP:Control Plane:05
REFERENCE	NIST SP 800-57
DESCRIPTION	The stored link ACA credentials the access-control service checks.

AST Asset Telemetry and ranging waveform AST:SI:Signal:01

ETEN nomenclature

> **AST:SI:Signal:01:The transmitted telemetry and ranging waveform: the modulated downlink signal, its framing, coding, and ranging tones.**

LAYER	**AST** Asset (L4)
TAG	**SI**
LABEL	Signal
ORDINAL	01
PARENT	SVC:HY:Hybrid:02
REFERENCE	CCSDS 132.0-B (TM Space Data Link); CCSDS TT&C
DESCRIPTION	The transmitted telemetry and ranging waveform: the modulated downlink signal, its framing, coding, and ranging tones.

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Ground segment assets (Reston) · each parents to a service within SEG:GR:Ground:00

AST Asset Ground ACA software

AST:SW:Software:02

ETEN nomenclature

> **AST:SW:Software:02:The ground software that enforces command acceptance before release to the link (ACA).**

LAYER	**AST** Asset (L4)
TAG	**SW**
LABEL	Software
ORDINAL	02
PARENT	SVC:CP:Control Plane:09
REFERENCE	Falco et al. 2024; NIST SP 800-57
DESCRIPTION	The ground software that enforces command acceptance before release to the link (ACA).

AST Asset ACA credential store

AST:DA:Data:01

ETEN nomenclature

> **AST:DA:Data:01:The stored ACA credentials the ground authentication service relies on.**

LAYER	**AST** Asset (L4)
TAG	**DA**
LABEL	Data
ORDINAL	01
PARENT	SVC:CP:Control Plane:09
REFERENCE	NIST SP 800-57
DESCRIPTION	The stored ACA credentials the ground authentication service relies on.

AST Asset Patch binaries (FW/SW)

AST:DA:Data:02

ETEN nomenclature

> **AST:DA:Data:02:The stored patch binaries, firmware and software, staged for deployment.**

LAYER	**AST** Asset (L4)
TAG	**DA**
LABEL	Data
ORDINAL	02
PARENT	SVC:CP:Control Plane:12
REFERENCE	NIST SP 800-40; NIST SP 800-193
DESCRIPTION	The stored patch binaries, firmware and software, staged for deployment.

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AST Asset **Patch deployment pipeline** **AST:SW:Software:03**

ETEN nomenclature

AST:SW:Software:03:The software pipeline that builds, signs, distributes, and installs patches.

LAYER	**AST** Asset (L4)
TAG	**SW**
LABEL	Software
ORDINAL	03
PARENT	SVC:CP:Control Plane:12
REFERENCE	NIST SP 800-40
DESCRIPTION	The software pipeline that builds, signs, distributes, and installs patches.

AST Asset **Operator console** **AST:HW:Hardware:04**

ETEN nomenclature

AST:HW:Hardware:04:The physical operator workstation from which telemetry is monitored and commands are issued.

LAYER	**AST** Asset (L4)
TAG	**HW**
LABEL	Hardware
ORDINAL	04
PARENT	SVC:CP:Control Plane:13
REFERENCE	NIST IR 8401
DESCRIPTION	The physical operator workstation from which telemetry is monitored and commands are issued.

AST Asset **Console operator software** **AST:SW:Software:04**

ETEN nomenclature

AST:SW:Software:04:The software C2 application on the operator console, the ground command-and-control suite.

LAYER	**AST** Asset (L4)
TAG	**SW**
LABEL	Software
ORDINAL	04
PARENT	SVC:CP:Control Plane:13
REFERENCE	NIST IR 8401
DESCRIPTION	The software C2 application on the operator console, the ground command-and-control suite.

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AST Asset **Ground cryptographic module (HSM)** **AST:HW:Hardware:05**

ETEN nomenclature

> **AST:HW:Hardware:05:The physical ground cryptographic module (HSM) that stores ground keys and performs encryption, decryption, signing, and verification.**

LAYER	**AST** Asset (L4)
TAG	**HW**
LABEL	Hardware
ORDINAL	05
PARENT	SVC:CP:Control Plane:08
REFERENCE	CCSDS 355.0-B (SDLS); NIST SP 800-57
DESCRIPTION	The physical ground cryptographic module (HSM) that stores ground keys and performs encryption, decryption, signing, and verification.

Ground segment assets (Kiruna) · each parents to a service within SEG:GR:Ground:01

AST Asset **Kiruna antenna and RF front end** **AST:HW:Hardware:08**

ETEN nomenclature

> **AST:HW:Hardware:08:The physical Kiruna antenna, feed, and low-noise / high-power RF front end.**

LAYER	**AST** Asset (L4)
TAG	**HW**
LABEL	Hardware
ORDINAL	08
PARENT	SVC:HY:Hybrid:03
REFERENCE	NIST IR 8401; CCSDS TT&C
DESCRIPTION	The physical Kiruna antenna, feed, and low-noise / high-power RF front end.

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