FP6 Thematic Areas – Results

Regional Rail CCS & Operations for G2 Lines

FP6-FutuRe Final Event · Brussels · 04/11/2026

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Results at a glance

1

Specified

A cost-effective CCS concept for G2 lines: fewer wayside assets, functions moved onboard and to the cloud

Introduction

2

Validated in the field

Onboard COTS positioning and train-to-cloud communication over commercial networks, assessed at TRL 6

Positioning & train-to-cloud

3

Control layer

Interlocking and RBC in one application, one database, virtual sections instead of trackside detection, assessed at TRL 4

Interlocking / RBC

The G2 challenge

1

Low traffic density

Revenue per km cannot carry mainline-grade CCS costs

2

Little or no trackside signalling

Outside the mainline interoperability scope (Dir. 2016/797/EU)

3

Constrained capital budgets

Many regional lines are at risk of downgrading or closure



Main CCS cost drivers: wayside equipment and cabling, and dedicated rail telecom networks

Result 1: a cost-effective CCS concept for G2 lines

1

Reduce wayside installations

Remove trackside positioning, train detection and lineside signals where possible

2

Move functions onboard and to data centres

Centralised, cloud-hosted applications sharing real-time data

3

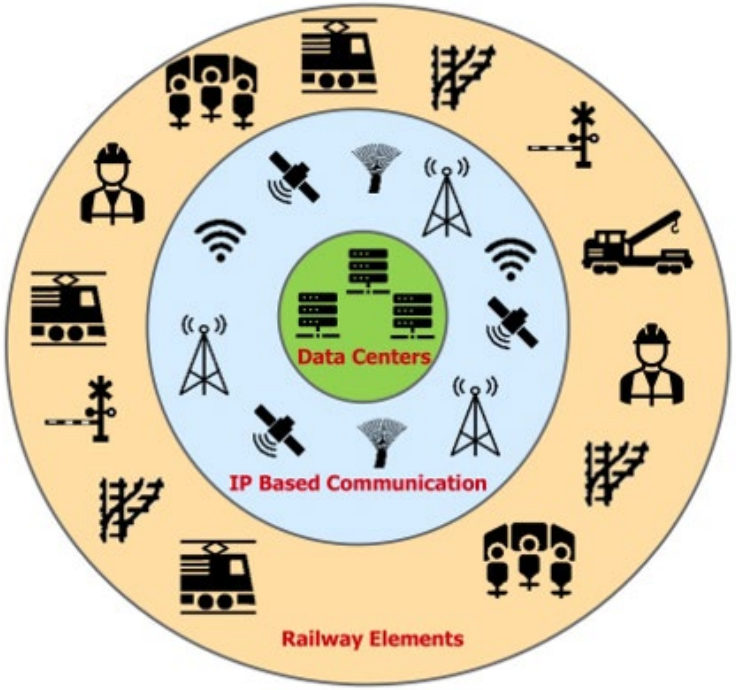
Decouple positioning from the application

Solution Pillar 2*: COTS positioning upgradable without touching railway apps

4

Communication-based train control

Solution Pillar 3*: GNSS + onboard track database; telecom-agnostic IP links



*From D5.2

KPI Targets and path to validation

−25%
CCS total cost of ownership

−15%
Communication & positioning costs

−30%
Wayside OPEX per km

+10%
System availability

Cost-effective fail-safe train positioning + **Train-to-cloud communication** + **Fail-safe cloud-based interlocking / RBC** → **Integrated demonstrator**

KPIs: *Validated in D5.2 by technological assumptions and architecture (Annex 3). Demonstration confirmed the assumptions. The full architecture will be demonstrated in wave 2.*

Source: FP6-FutuRe D5.2 – Specification CCS for Group 2; Grant Agreement 101101962

Field demonstrator on a freight train in revenue service

2

days of tests
(27-28 July 2026)

4

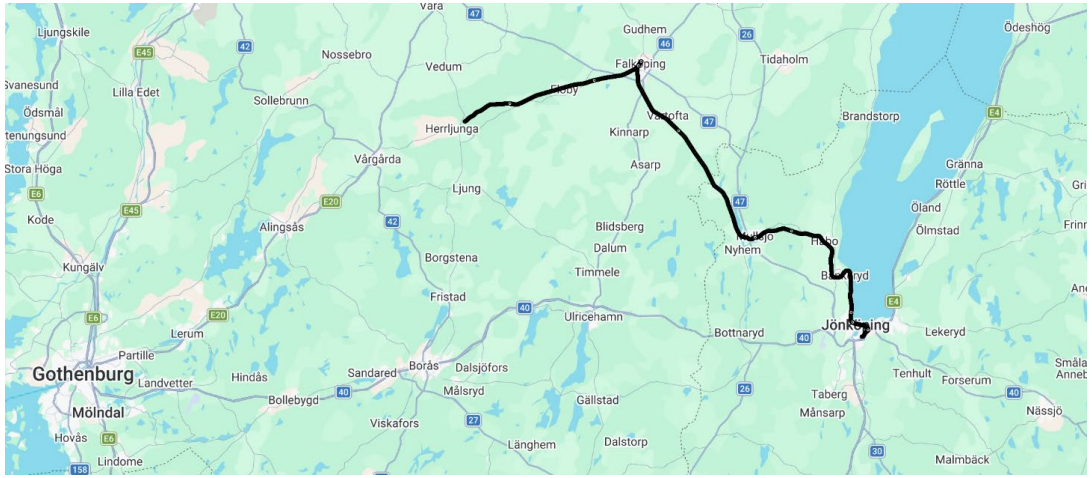
runs in normal
revenue service

~210 km

travelled across
the four runs

0

trackside devices
installed

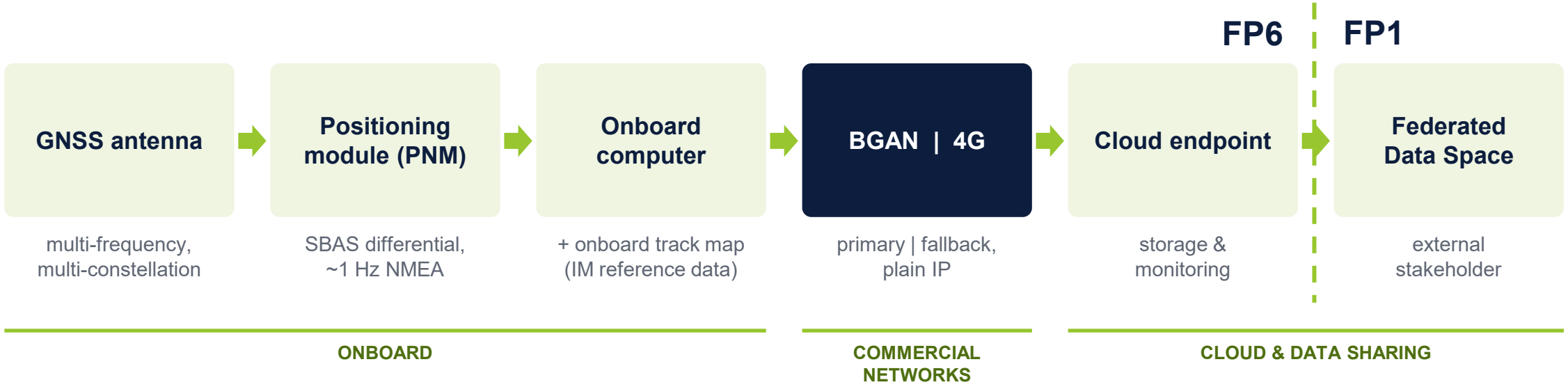




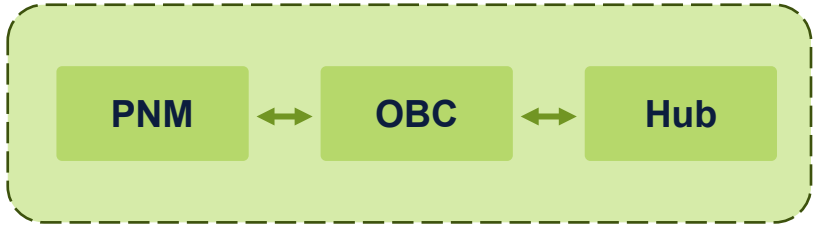
Nässjö-Göteborg line (Sweden), Jönköping–Herrljunga section · SHN Cargo freight locomotive · one self-contained onboard unit, no vehicle modification

Partners: FT (Wabtec) · Trafikverket

One onboard unit, any bearer, straight to the cloud



Telecom-agnostic by design: the railway application does not depend on which bearer carries the data, so networks can evolve (4G → 5G, other satellite providers) without re-engineering.



Result 2: positioning without trackside equipment

>95%

of records with a differential GNSS fix (avg. 18 satellites, mean HDOP 0.65)

On track

matched to a mapped track at almost every check after anchoring; isolated misses recovered at the next check

~0.3 m

GNSS-related lateral deviation, estimated from day-to-day repeatability

32

turnout-proximity events detected from IM reference data

What limits the result is the map

1. Positions and map were brought into the same reference frame and corrected for the antenna position.
2. The remaining deviation repeats at the same places on both days, so it comes from the map geometry.
3. The satellite-positioning is at the decimetre level.
4. Next step: a surveyed reference trajectory, to measure absolute accuracy.

~14,400 records at ~1 Hz

Consistency with the reference map, both days; no independent reference trajectory.

Result 3: train-to-cloud over commercial networks

~14,400

positioning messages logged & pulled on demand: train → cloud

Auto

BGAN ↔ 4G fallback without intervention

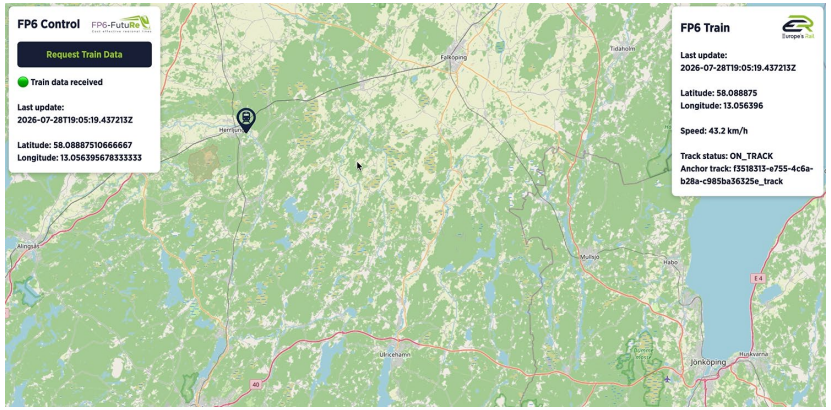
~75 s

autonomous recovery after a real power interruption

Federated Data Space

data consumed by an external stakeholder via a dataspace connector

```
[root@GRIO-E:~# route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         192.168.128.100 0.0.0.0         UG    0      0        0 eth0
one.one.one.one 10.255.255.1    255.255.255.255 UGH   0      0        0 eth0
one.one.one.one 192.168.128.100 255.255.255.255 UGH   0      0        0 eth0
10.255.255.0    0.0.0.0         255.255.255.0   U     0      0        0 eth0
192.168.128.0   0.0.0.0         255.255.255.0   U     0      0        0 eth0
[root@GRIO-E:~#
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Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         10.255.255.1    0.0.0.0         UG    0      0        0 eth0
one.one.one.one 10.255.255.1    255.255.255.255 UGH   0      0        0 eth0
one.one.one.one 192.168.128.100 255.255.255.255 UGH   0      0        0 eth0
10.255.255.0    0.0.0.0         255.255.255.0   U     0      0        0 eth0
192.168.128.0   0.0.0.0         255.255.255.0   U     0      0        0 eth0
root@GRIO-E:~#
```



On G2 lines, losing the link affects availability, not safety.

Fail-safe design brings the train to a safe state; the trade-off is weighed against the cost of dedicated rail telecom.

Source: FP6-FutuRe D9.10 – G2 Regional Lines of Train-to-Cloud Communications

What the results mean

Technology readiness



TRL 6 for the positioning and communication functions exercised in revenue service.

KPIs: Validated in D5.2 by technological assumptions and architecture (Annex 3). Demonstration confirmed the assumptions. The full architecture will be demonstrated in wave 2.

Open points and next steps

Integrity & certification

integrity monitoring and SIL-oriented safety case not yet assessed

Accuracy reference

independent reference trajectory needed for absolute accuracy

RTK & odometry

supported by the positioning module, not yet used

Vehicle integration

fixed antenna and permanent power supply; IM data scope agreed upfront

Result 4: interlocking and RBC in one application

1

application and one configuration database for IxL and RBC functions

20

virtual sections – no track circuits or axle counters

14

operational scenarios, including degraded modes

TRL 4

validated in the laboratory (GA target TRL 4/5)

How it works

Train reports

position, length and state once per second, over IP

→

Virtual-section occupancy

map matching, occupied from tail to head

→

Separation & station logic

routes formed only into a free station

→

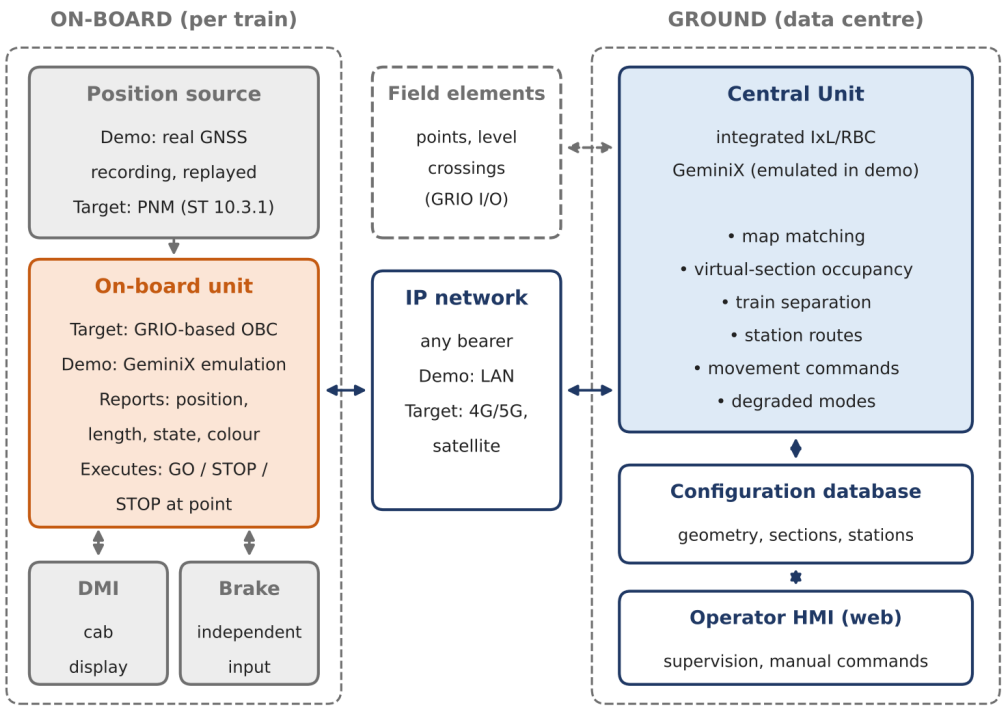
Movement command

GO · STOP · STOP at point, shown as cab colour code

KPIs: *technology assumptions validated in the laboratory; KPI values from the D5.2 (Annex 3).*

Source: FP6-FutuRe D10.4 v1.2 (draft) – Ch. 3 and Annex 2 (ST 10.3.2)

Interlocking / RBC: architecture and demonstrator



1 — COTS safety platforms

GeminiX-based central unit and GRIO-based on-board computers, designed for SIL 4; emulated in the demonstration

2 — Real line, replayed

two 150 m trains replaying real GNSS recordings of the Jönköping-Herrljunga section

3 — IP only, bearer-agnostic

local Ethernet in the lab; the BGAN / 4G bearers of the field demo with an EN 50159 safety layer in the target

4 — A small, shared data set

on-board and ground exchange only a few well-defined data: a first step towards data-centric interoperability

Source: FP6-FutuRe D10.4 v1.2 (draft) – Annex 2 §10.2.4–10.2.6; Annex 3

What was demonstrated

1 **Automatic separation**

the following train stops at the boundary of the occupied section and restarts when it is released

2 **Station protection**

a route is formed and validated only into a free station; otherwise, it is denied

3 **Independent on-board braking**

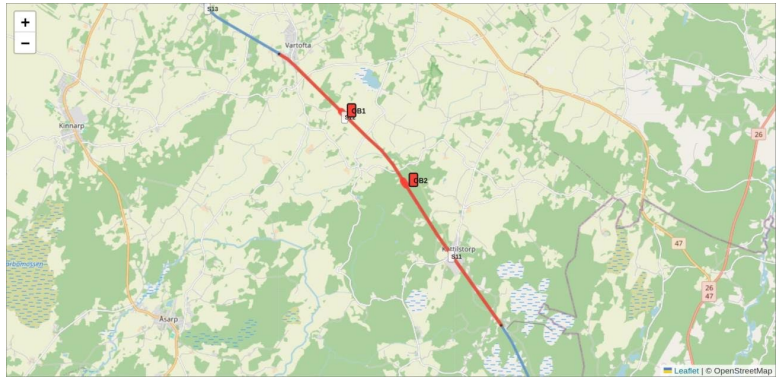
the train can always be stopped locally, without withdrawing the ground authority

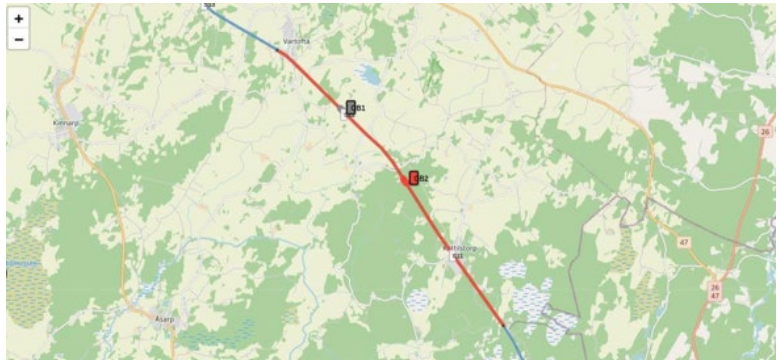
4 **Manual operator commands**

immediate stop, stop at a geographical point, authorisation to proceed

5 **Loss of communication**

a silent train's sections stay occupied: no information means no release





Laboratory demonstration on the GeminiX emulation environment; communication loss tested with a stationary train only. Source: D10.4 v1.2 §10.2.7–10.2.10

Toward integrated demonstration – next waves

Layer 1	**Functional validation**	Achieved: positioning & communication (field); integrated IxL / RBC (laboratory)	**Achieved**
Layer 2	**Data integration**	Achieved: positioning data through the train-to-cloud layer	**Achieved**
Layer 3	**Functional interaction**	Partially reached in the laboratory: IxL / RBC driven by replayed real GNSS data over IP	**Partial**
Layer 4	**Extended integration**	Not reached in Wave 1: needs live positioning, communication, IxL/RBC and FDS/cloud together	**Next waves**

Next, for the integrated demo: target hardware · live positioning on a running train · real bearers with EN 50159 · train integrity, points and level crossings · safety case

Integration levels as defined in D7.6; status from FP6-FutuRe D10.4 v1.2 (draft) §5.2 and §10.2.12

Wrap-up

Key takeaways

1 **G2 lines need a different CCS**

fewer wayside assets, functions onboard and in the cloud, decoupled from telecom and positioning technology

2 **The enablers work on a real line**

COTS onboard positioning and commercial train-to-cloud communication assessed at TRL 6 in revenue service

3 **Next: close the loop with control**

cloud-based interlocking / RBC and integrated demonstration, plus integrity and certification of positioning

Thank you

Partners in the field demonstration

Faiveley Transport (Wabtec): demonstrator leader
Trafikverket: demonstration partner, infrastructure manager
Ferrovie dello Stato Italiane: FP1 / WP31 dataspace partners

This project has received funding from the Europe's Rail Joint Undertaking (JU) under grant agreement 101101962. The JU receives support from the European Union's Horizon Europe research and innovation programme and the Europe's Rail JU members other than the Union.

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