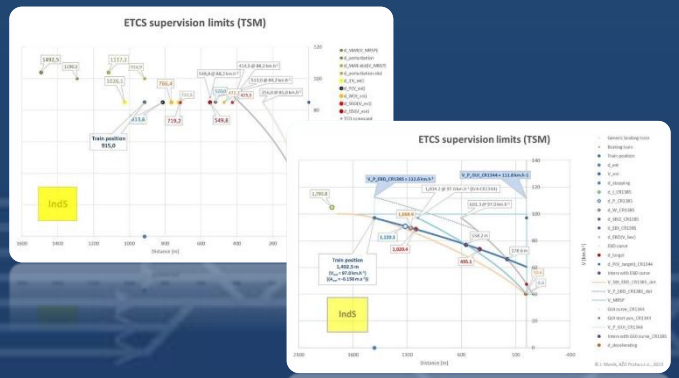
AŽD Praha s.r.o.

ETCS Braking curves: What has been done and what can still be improved/optimised?

Jakub Marek

UNISIG Braking curves TF Leader, representing the AŽD Praha company

UNISIG Super Group Leader, representing the AŽD Praha company

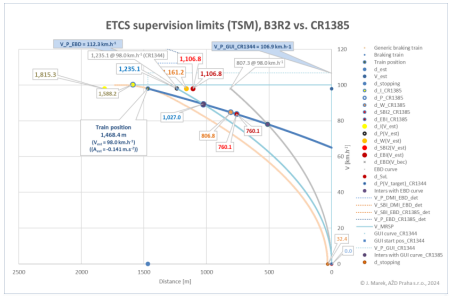


AŽD forum at InnoTrans 2024 / Berlin, 25th and 26th September 2024

Let’s join a journey towards better ETCS

Let’s join a journey towards better ETCS (speed & dist. sup.)

ETCS of today



ETCS of tomorrow

Motivation

- Would we like to see this?

Motivation

- Would we like to see this?

Motivation

- Or this?

Motivation

- Or this?

Motivation

- Or rather this?

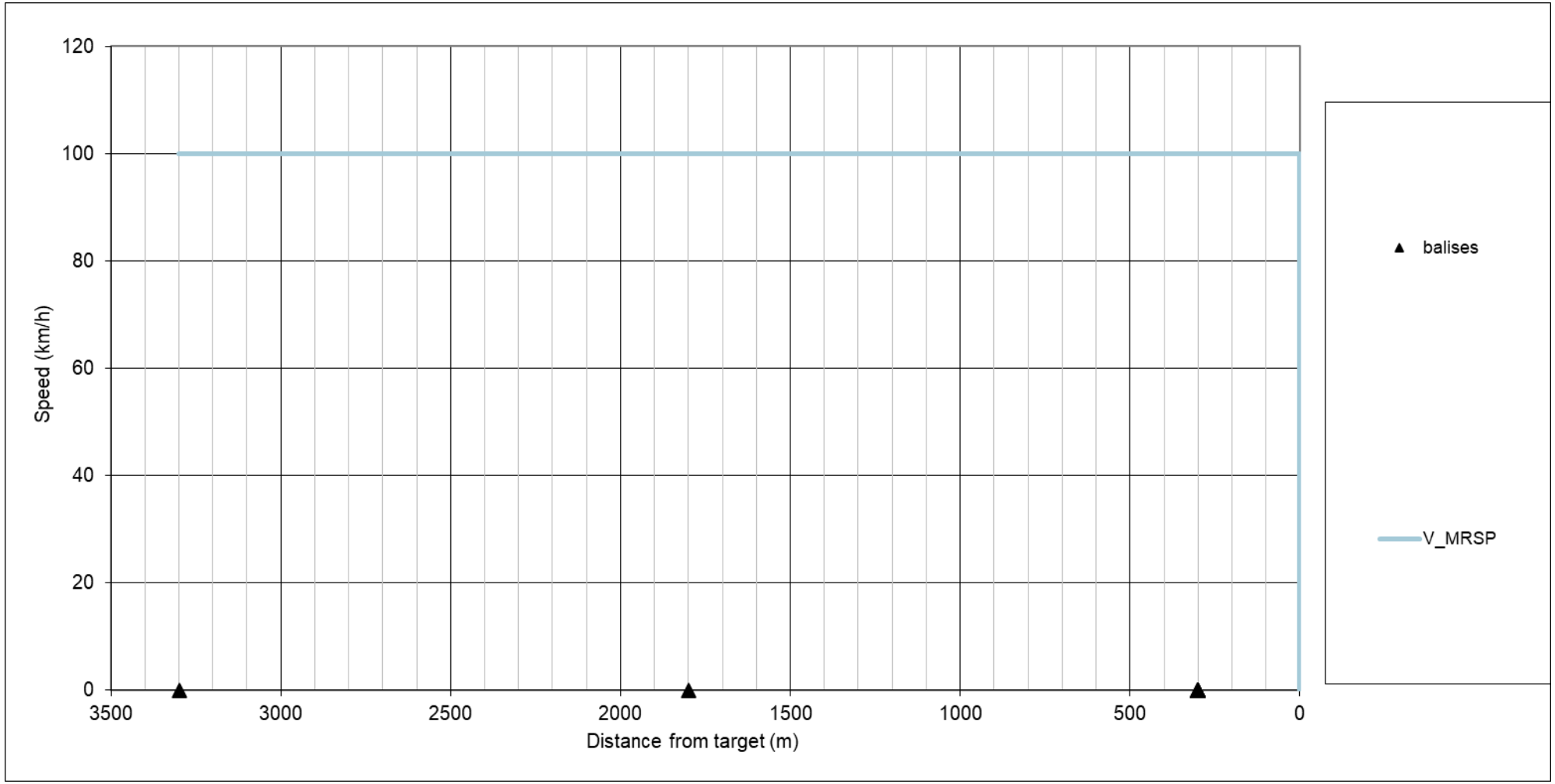
Motivation

- Or rather this?

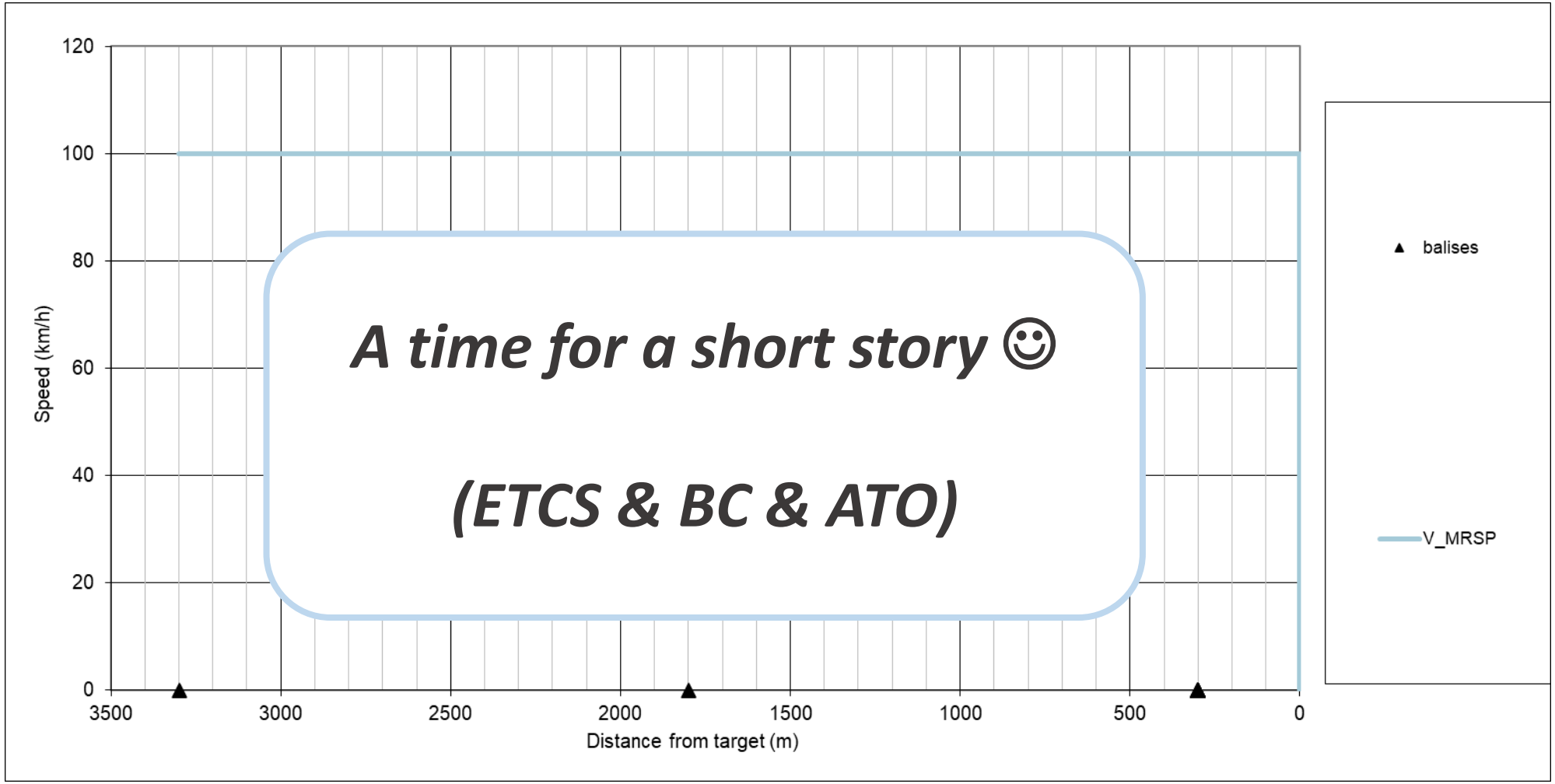
How did the journey begin?

- Will this train be further braked by the B3R2 ERTMS/ETCS OBU?

Will this train be braked by the B3R2 ETCS OBU?



Will this train be braked by the B3R2 ETCS OBU?



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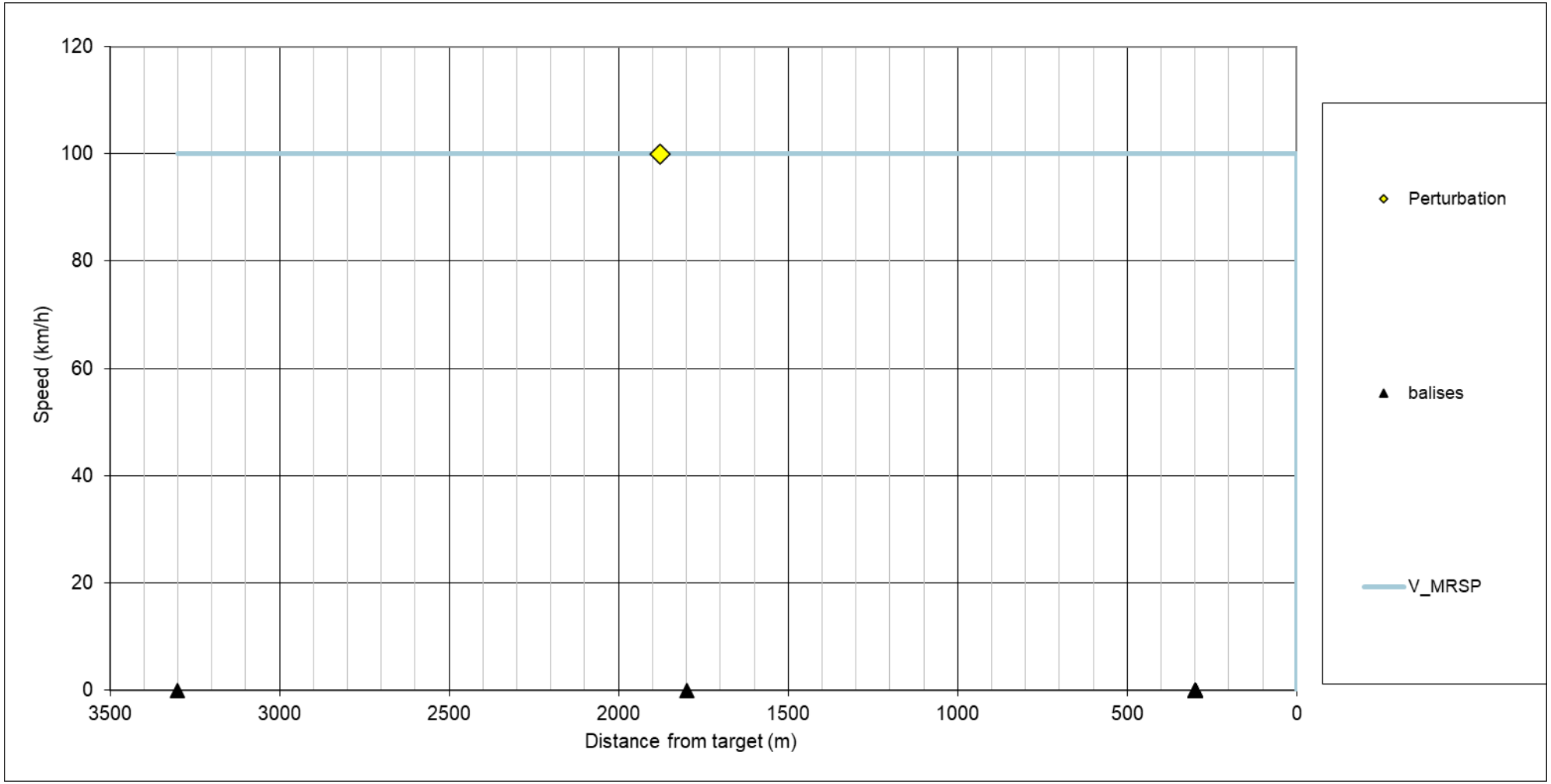

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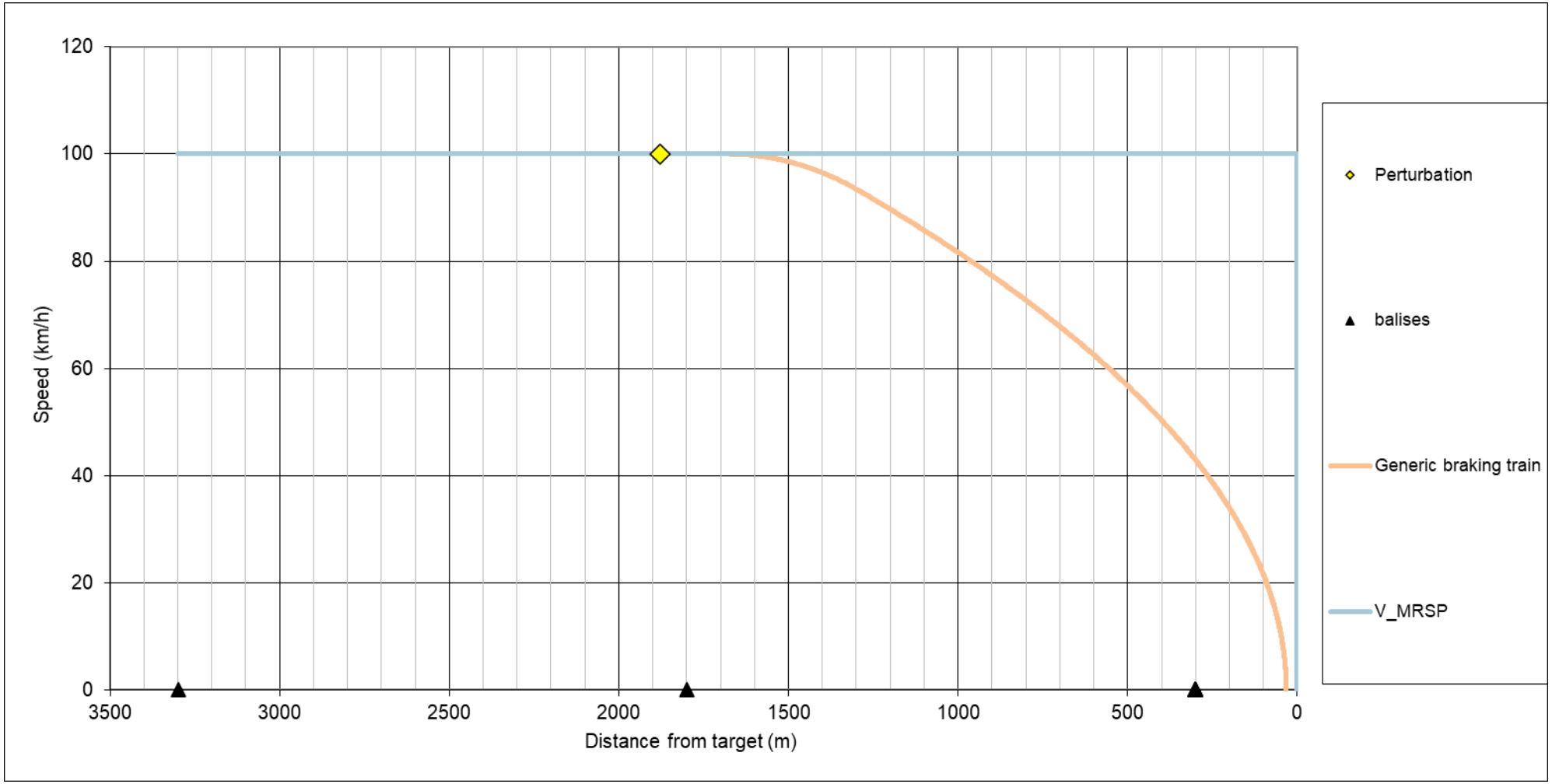

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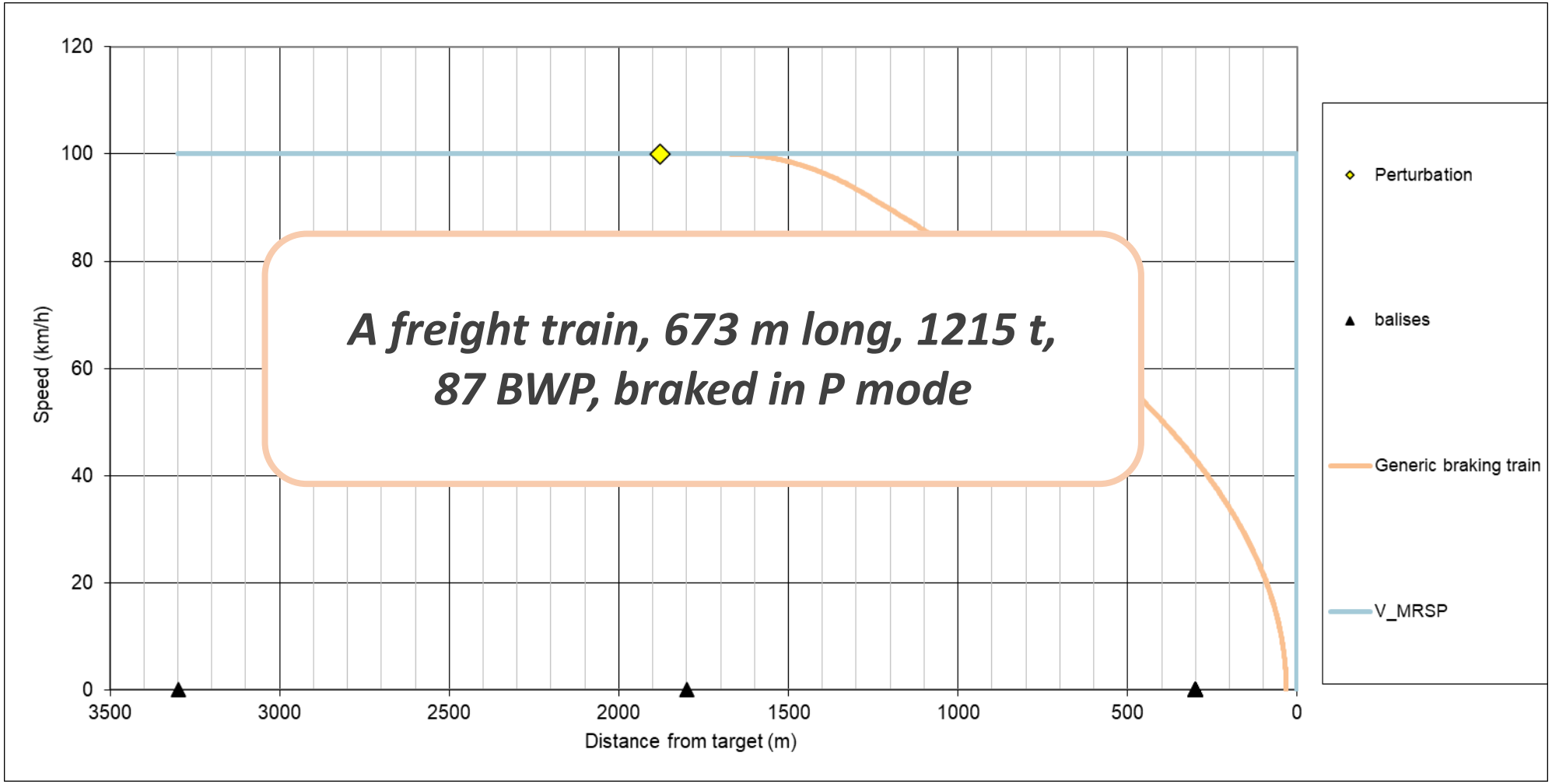

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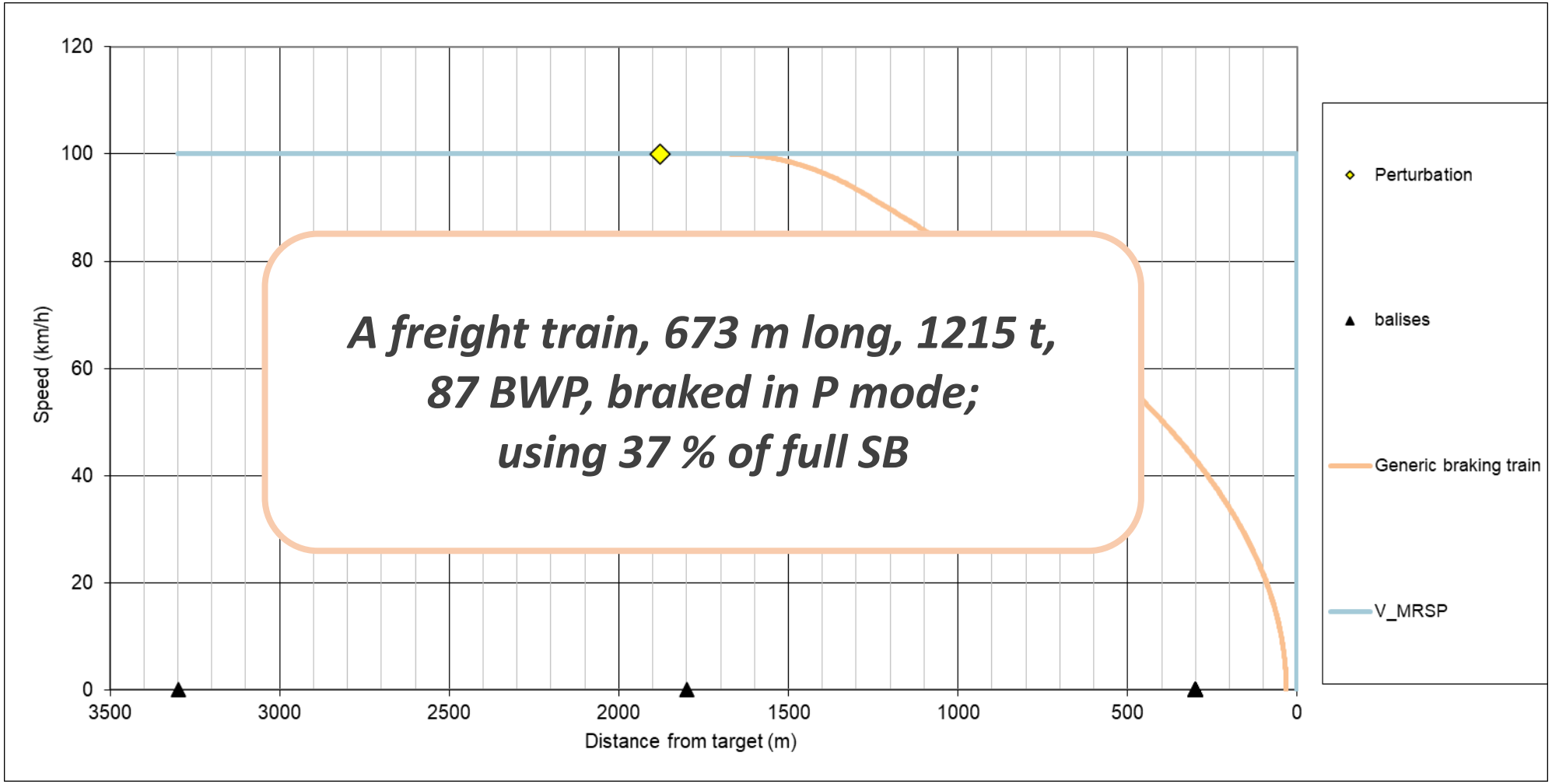

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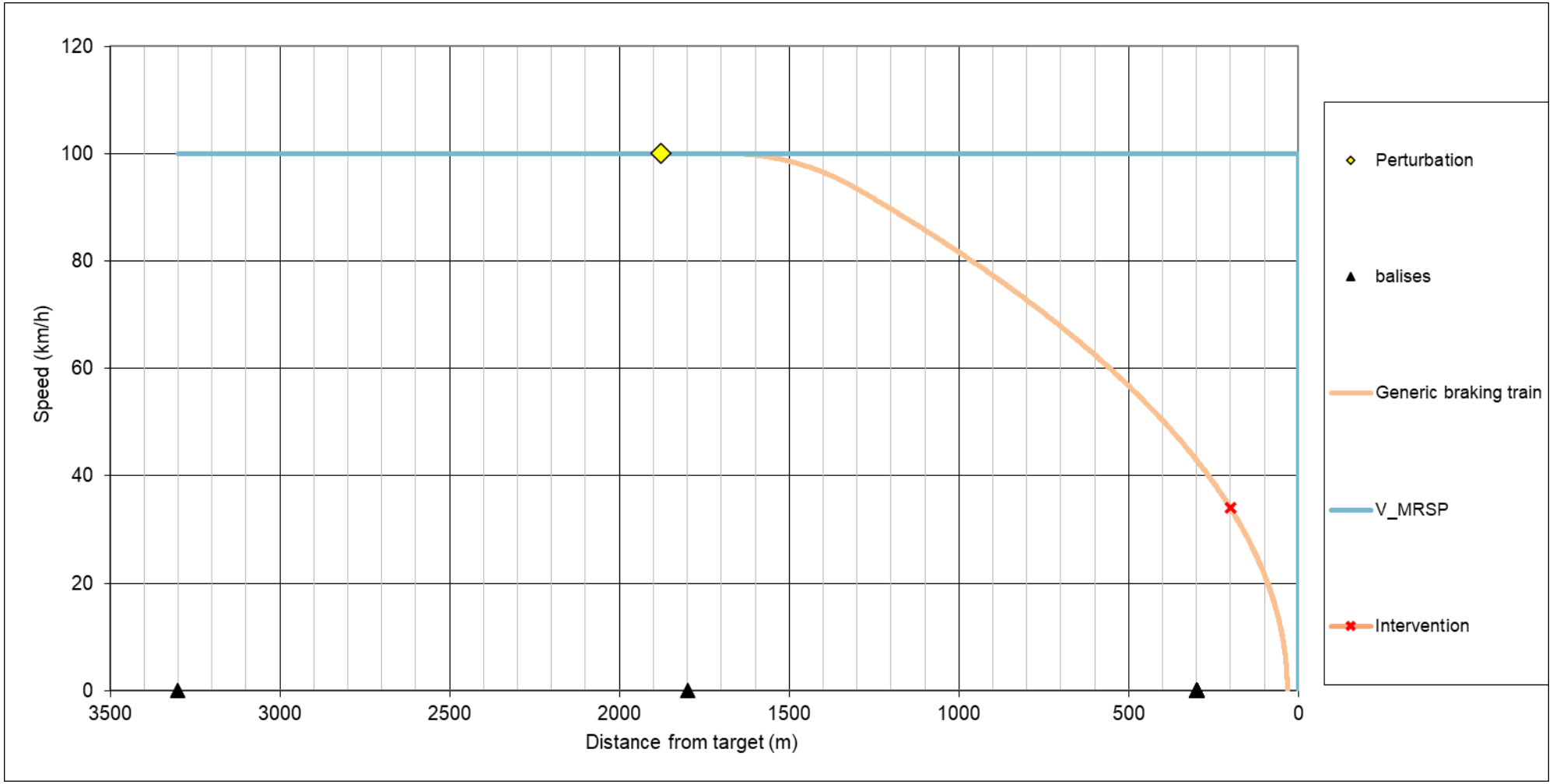

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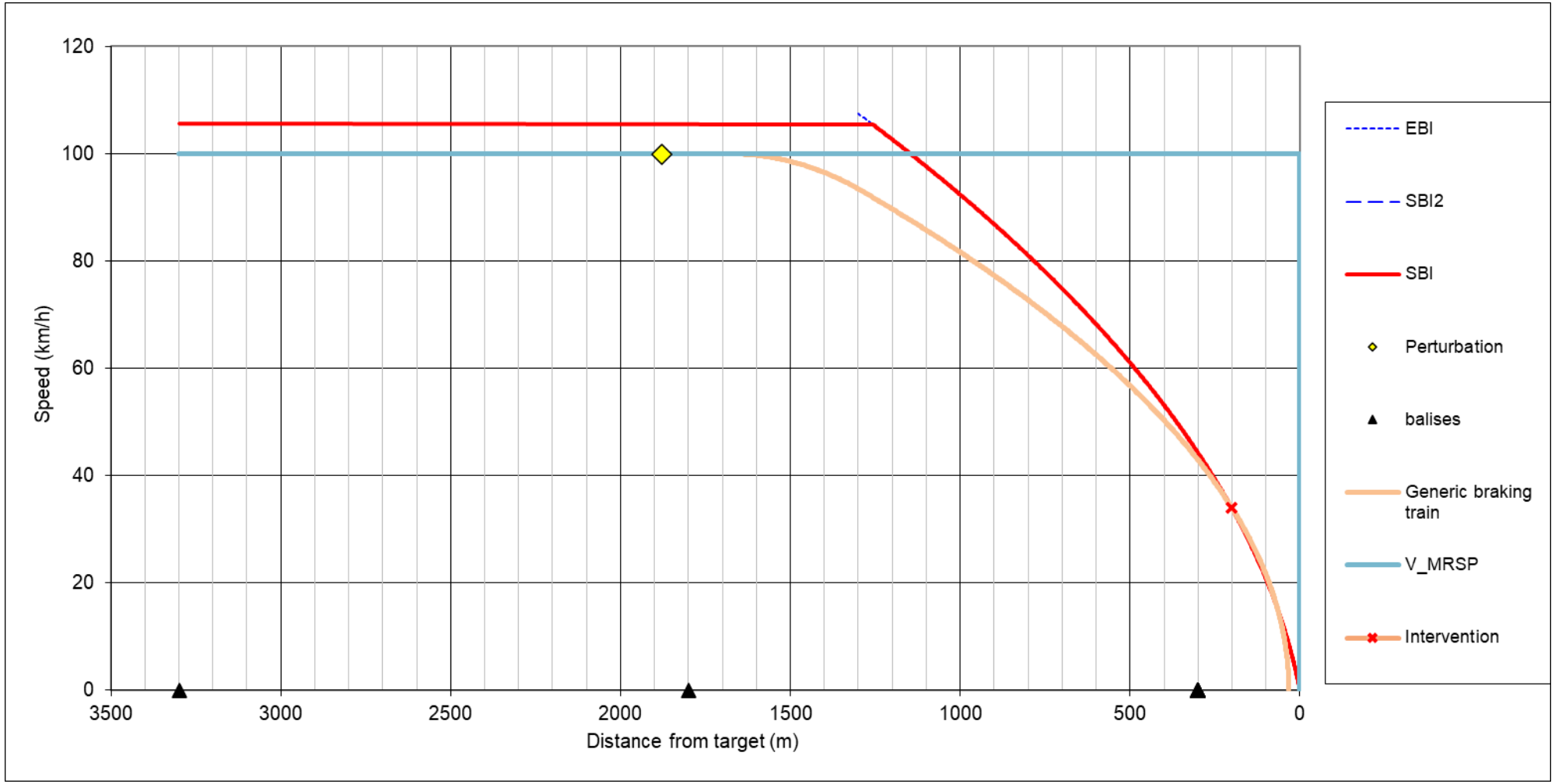

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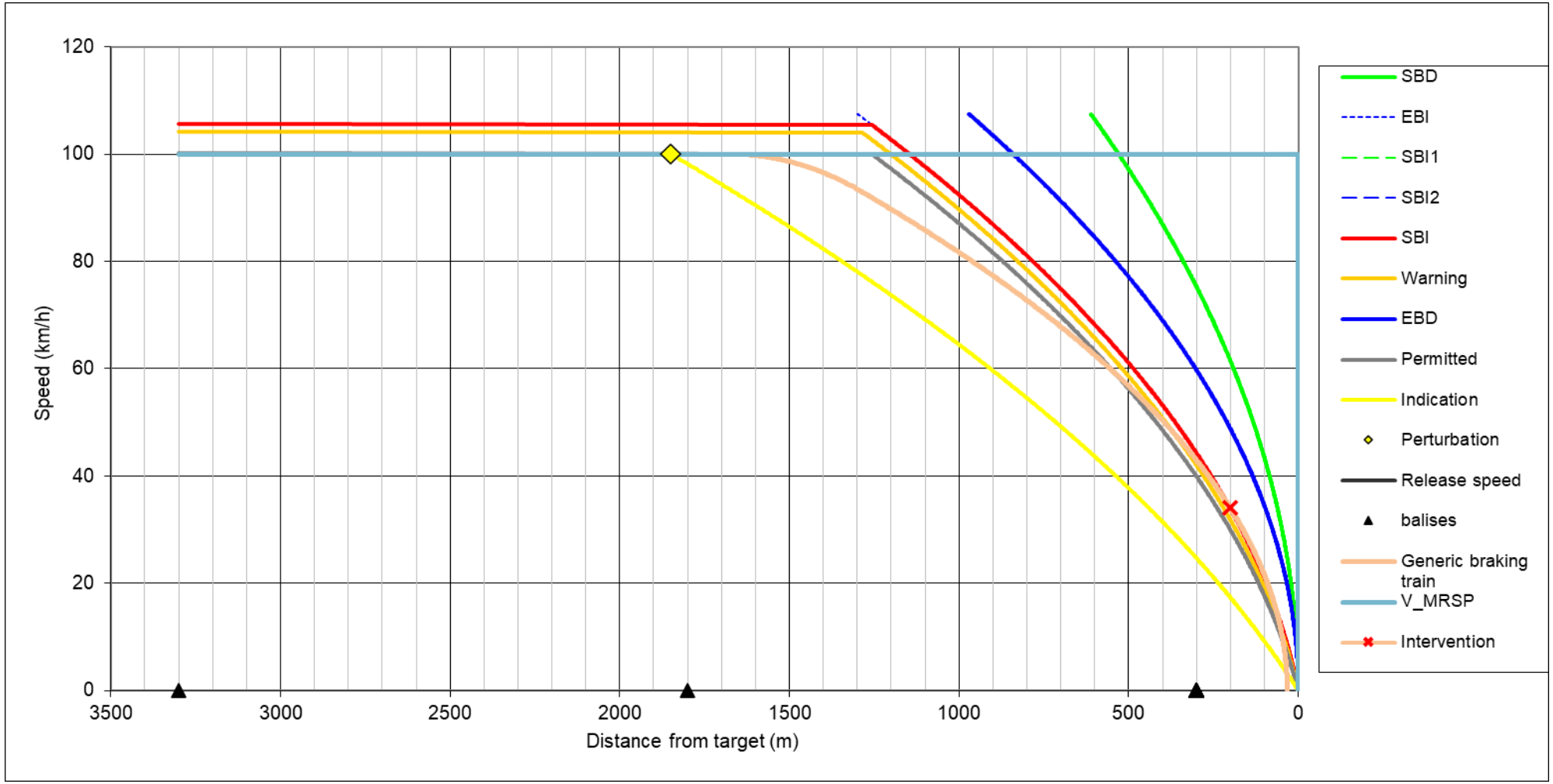

What did we find out?

- There are **two assumptions** in the ETCS BC computation **that can be removed**:
  - assumption of a constant (accelerating) train speed
  - assumption of a constant brake build-up time

SIGNAL+DRAHT (112) 3+6/2020

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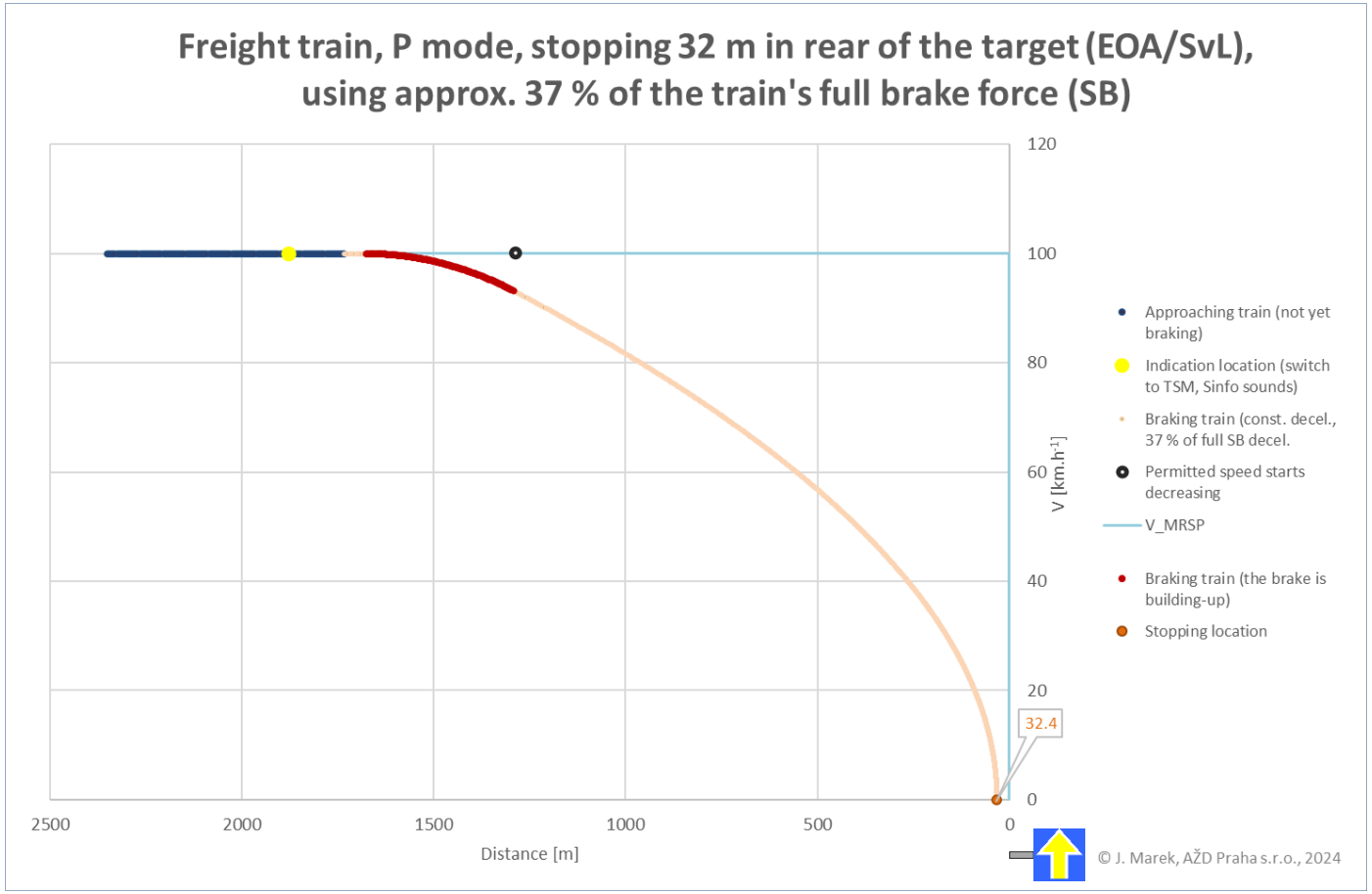
SIGNAL+DRAHT (112) 3+6/2020

CR1385 (better handling with the measured decel.)

- **Principle: Braking enough ⇒ remove the ETCS supervision limits**



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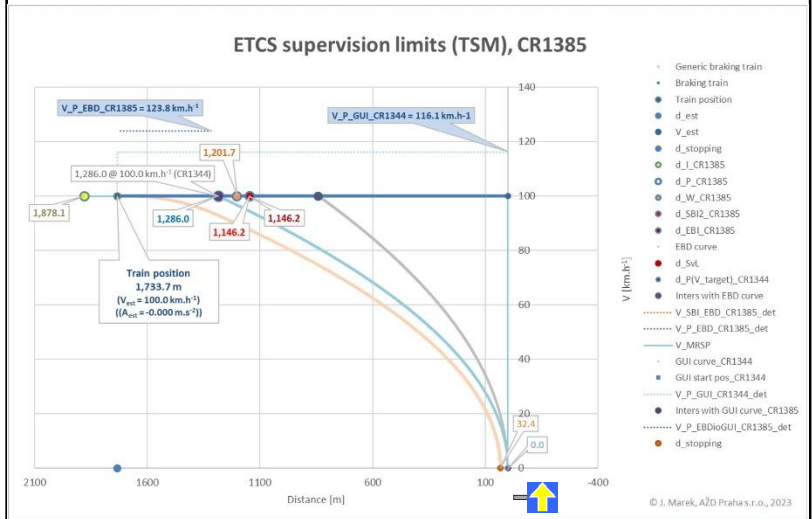
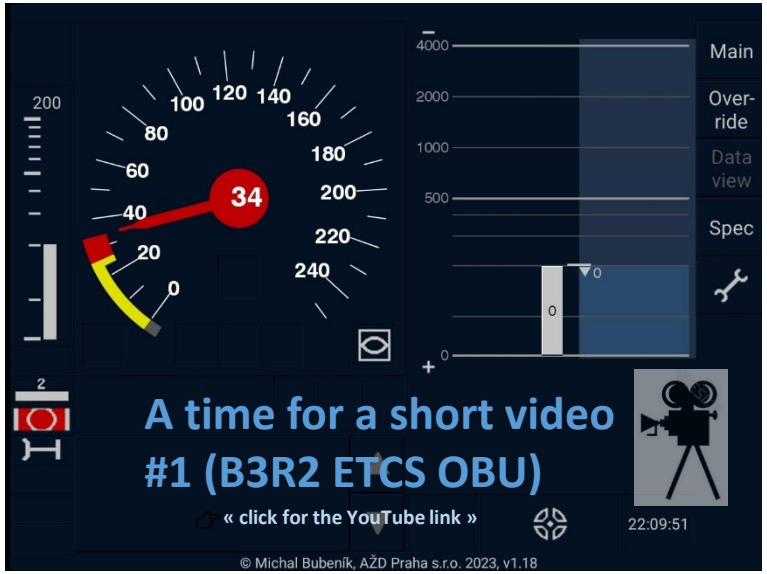
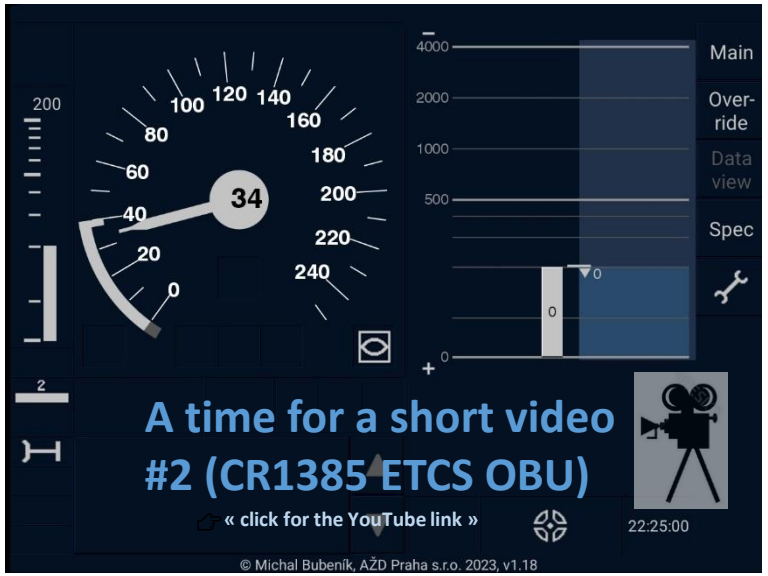
Locations of the ETCS supervision limits acc. to [B3R2 SUBSET-026] vs. [CR1385]	Corresponding display on the DMI – calculations according to	
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
*) The train is braking to a stand with 37 % of its full SB application, stopping 32 m in rear of the EOA/SvL		
		

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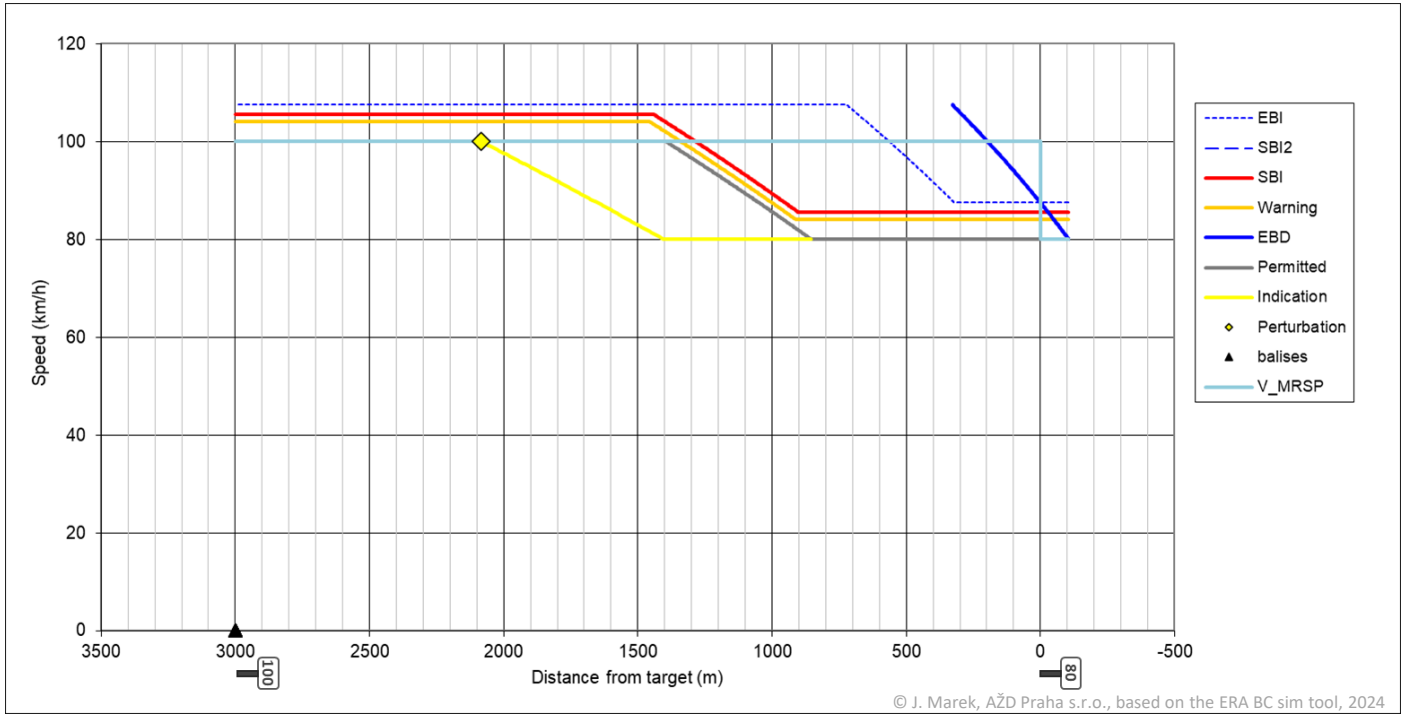
- **Principle: Braking enough ⇒ remove the** ETCS supervision **limits**
  - To understand what is to be done, we need to go **from the ETCS curves to the ETCS supervision limits**, as the OBU sees them – curves:



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- **Principle: Braking enough ⇒ remove the** ETCS supervision **limits**
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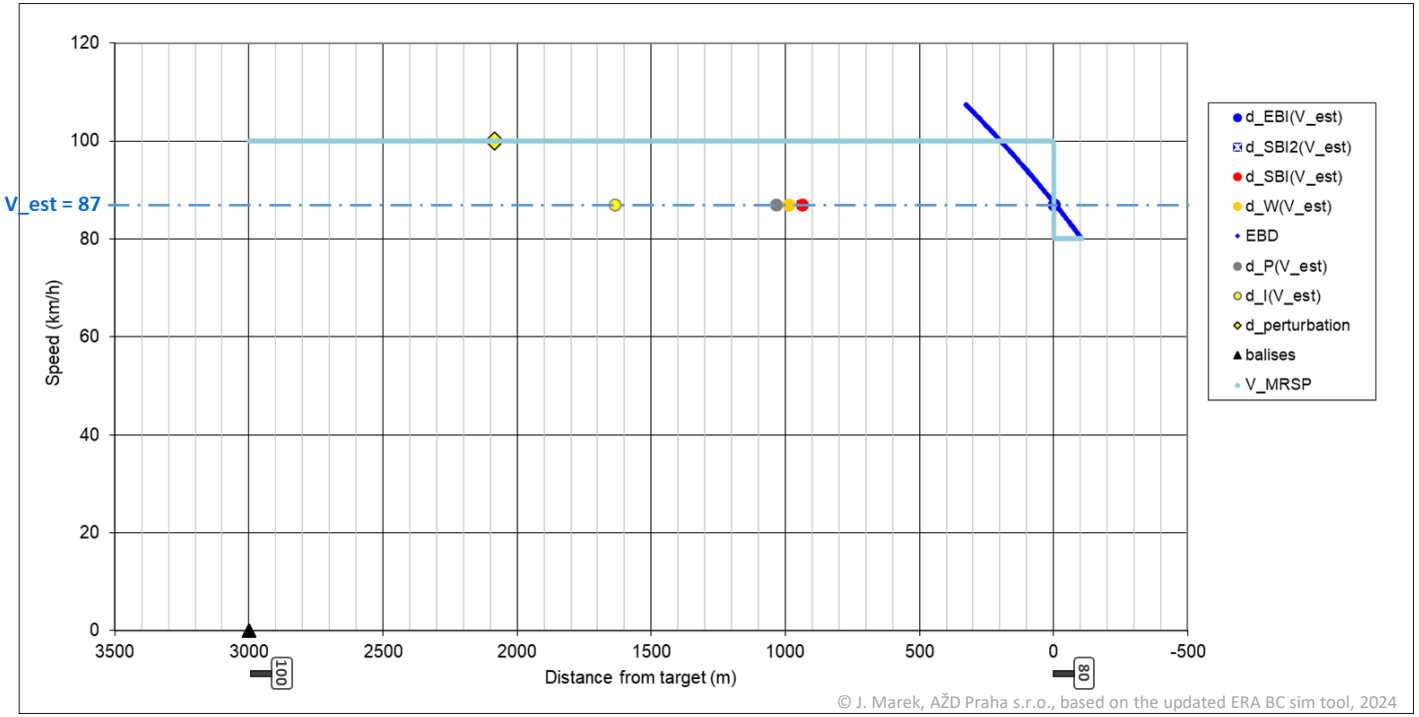

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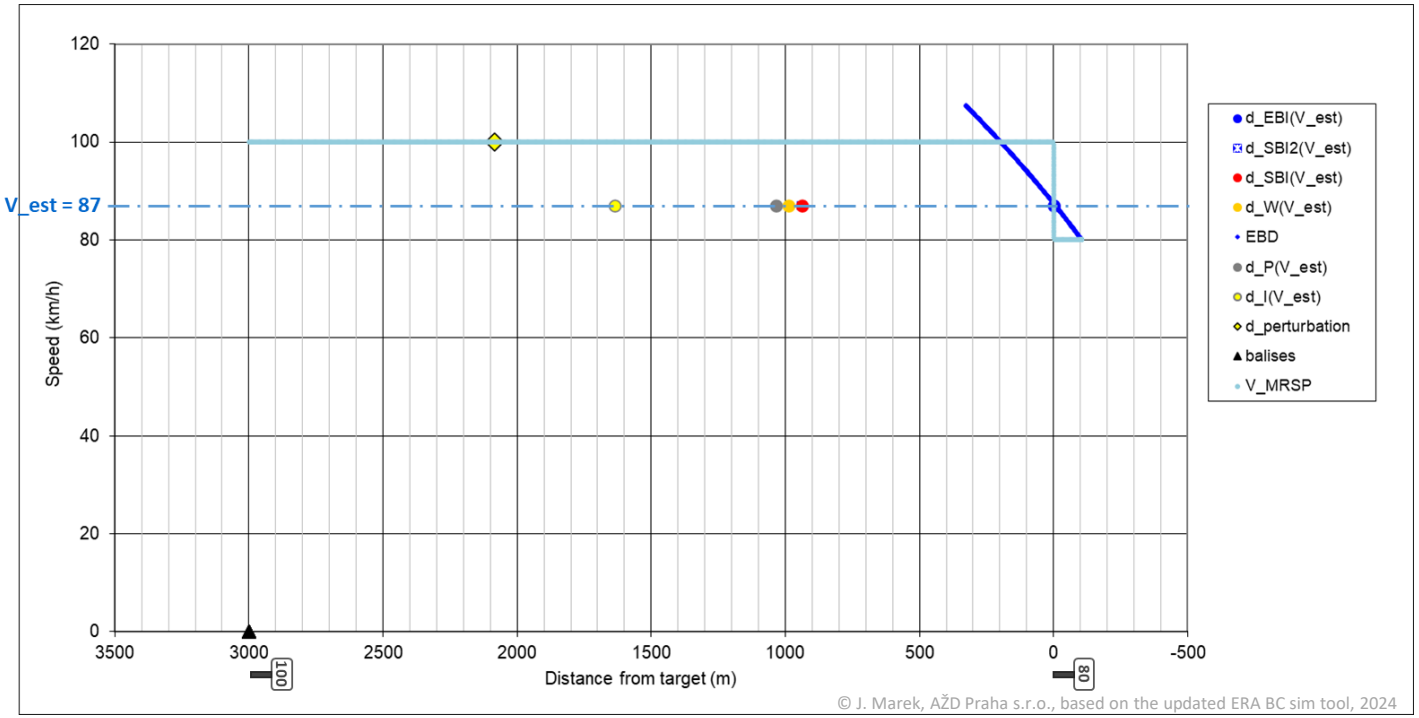

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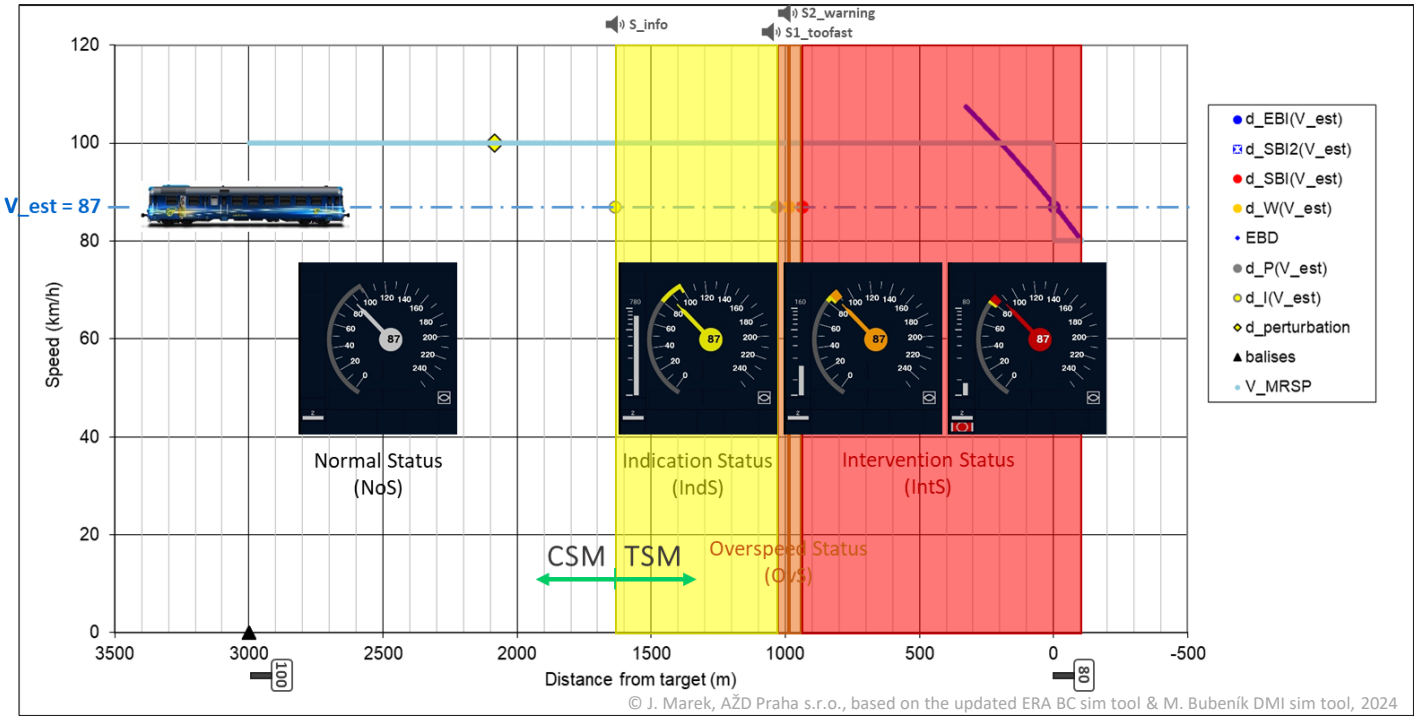

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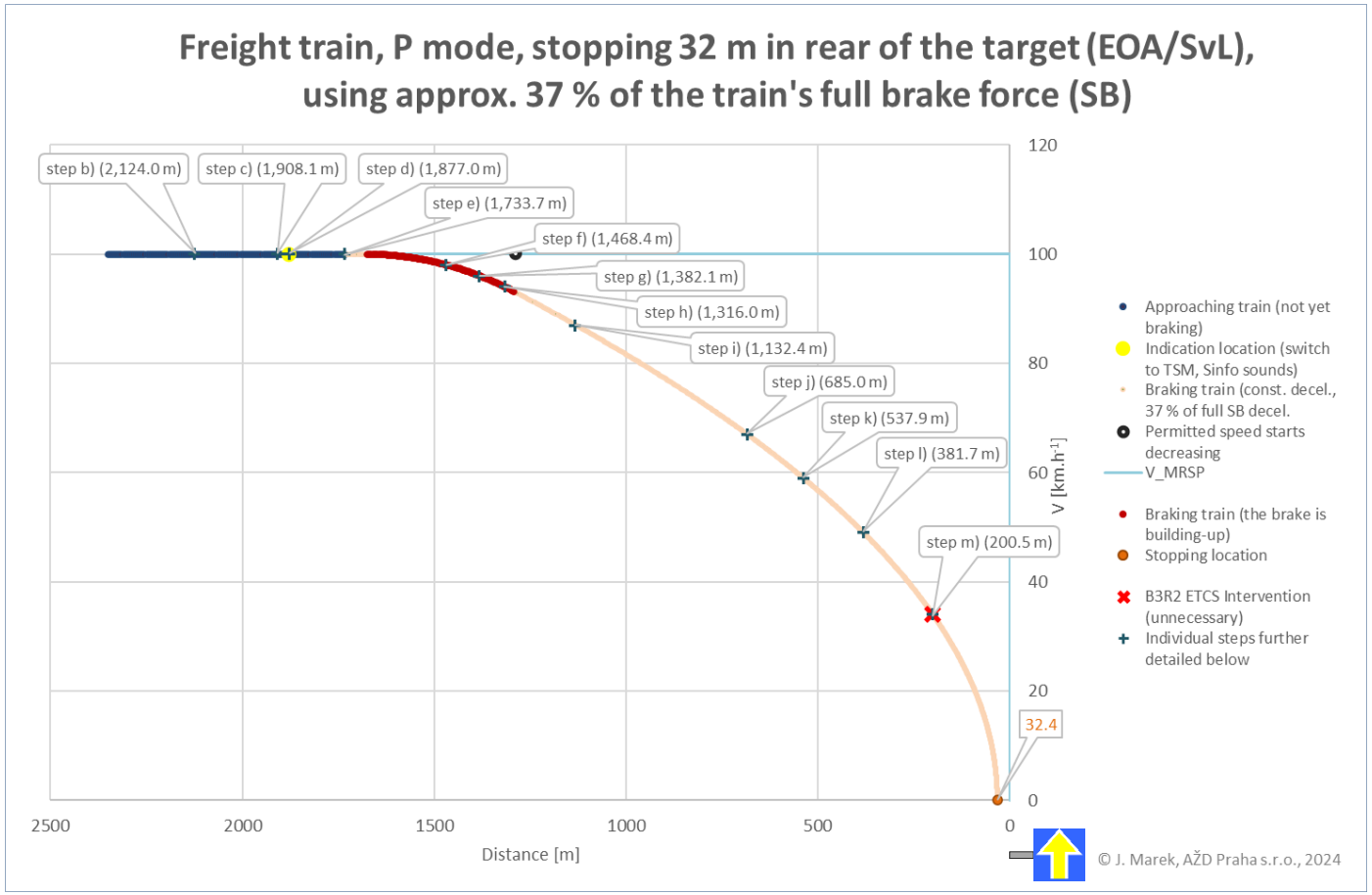

What is different?

- How can the ETCS supervision limits consider that the train is already braking?

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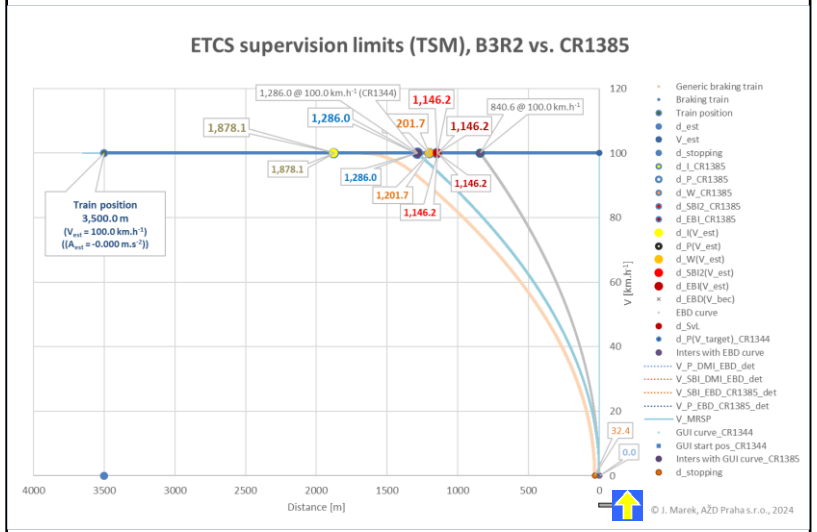
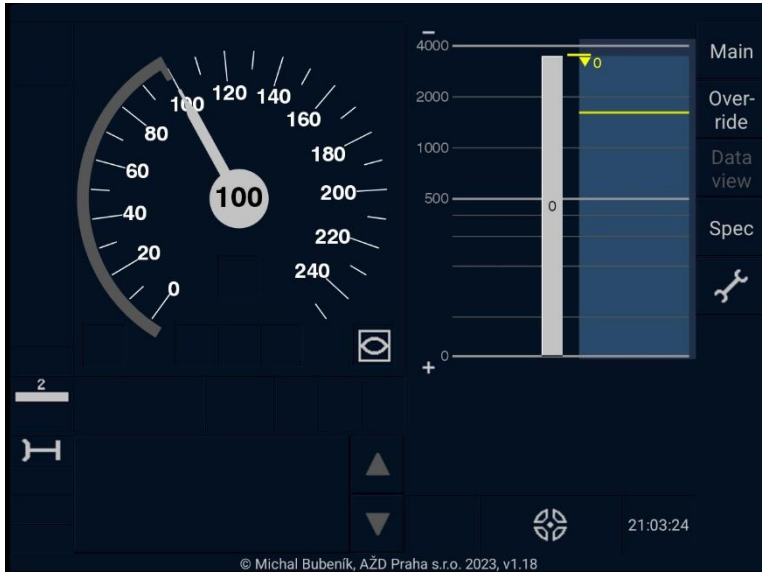
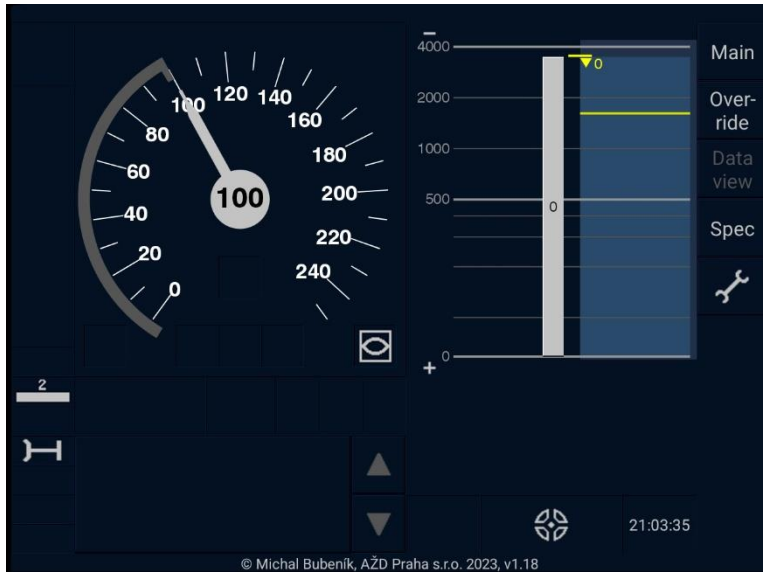
- Principle: For the trains braking enough (A_{est}), remove the ETCS BCs

Locations of the ETCS supervision limits acc. to [B3R2 SUBSET-026] vs. [CR1385]	Corresponding display on the DMI – calculations according to	
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
a) The train is approaching a target (EOA/SvL), d_{est} = 3,500 m, V_{est} = 100 km.h^{-1}, A_{est} = 0 m.s^{-2}		
		

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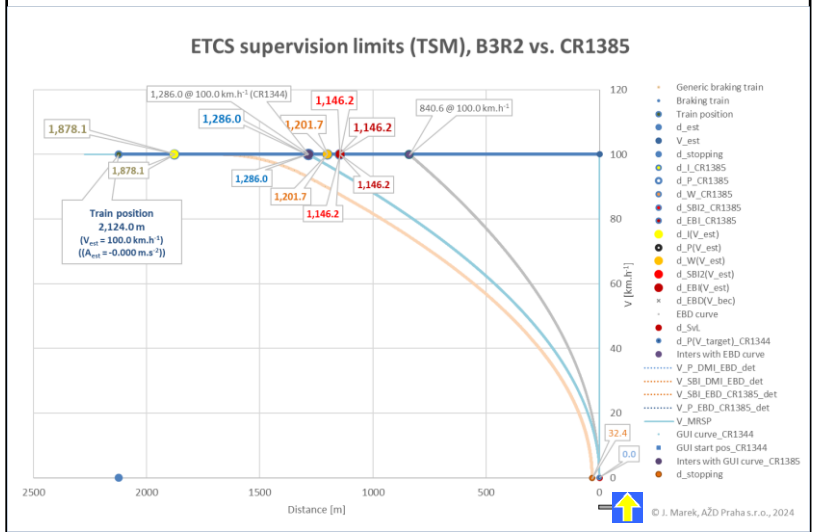
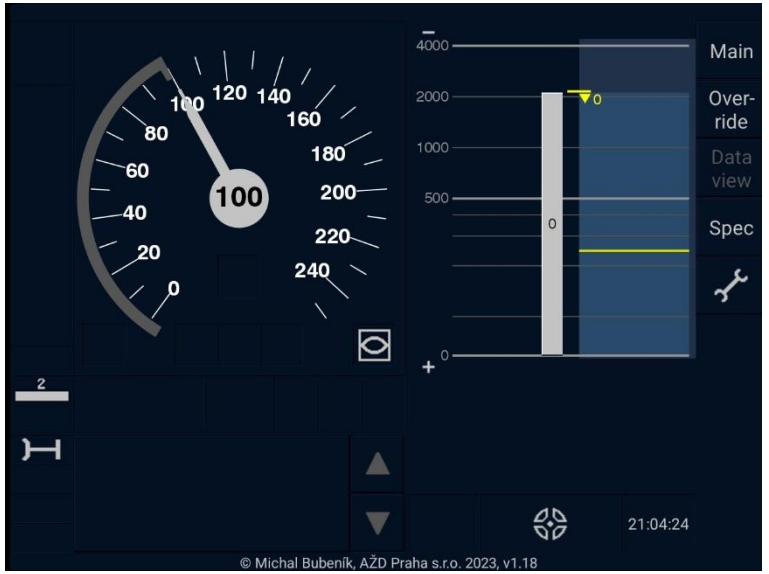
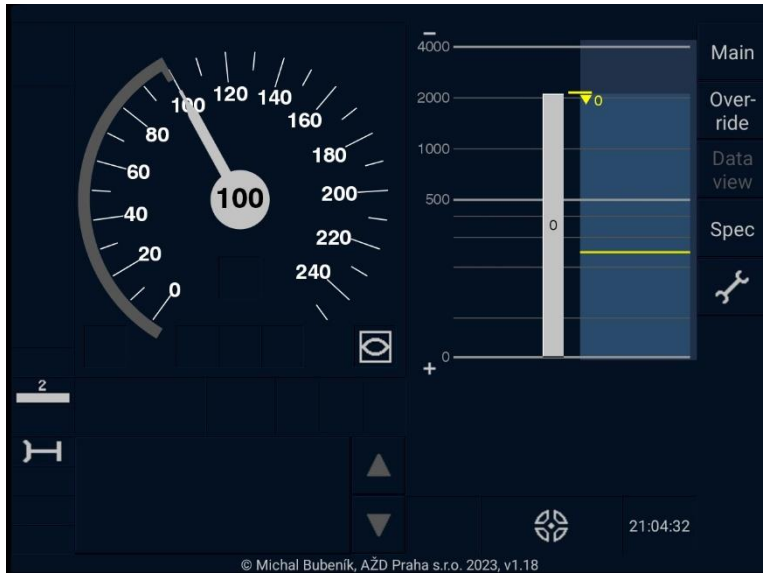
b) The train is approaching a target (EOA/SvL), d_{est} = 2,124 m, V_{est} = 100 km.h^{-1}, A_{est} = 0 m.s^{-2}		
		

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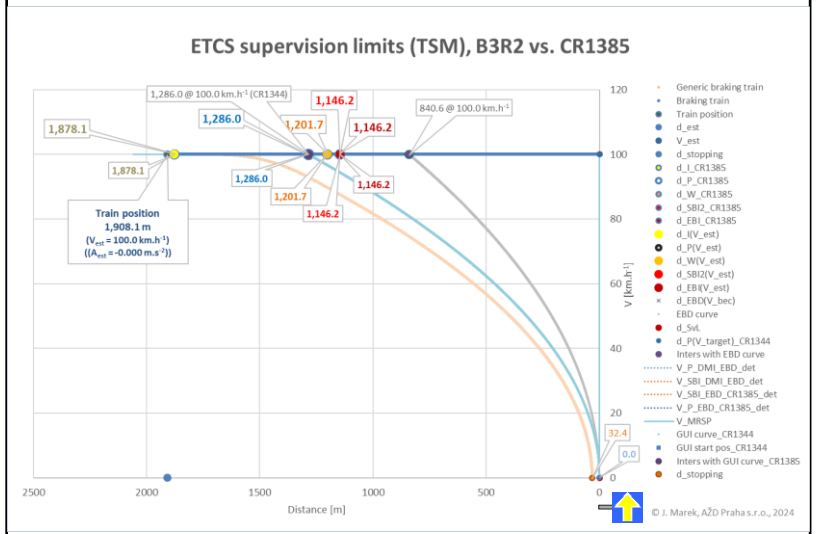
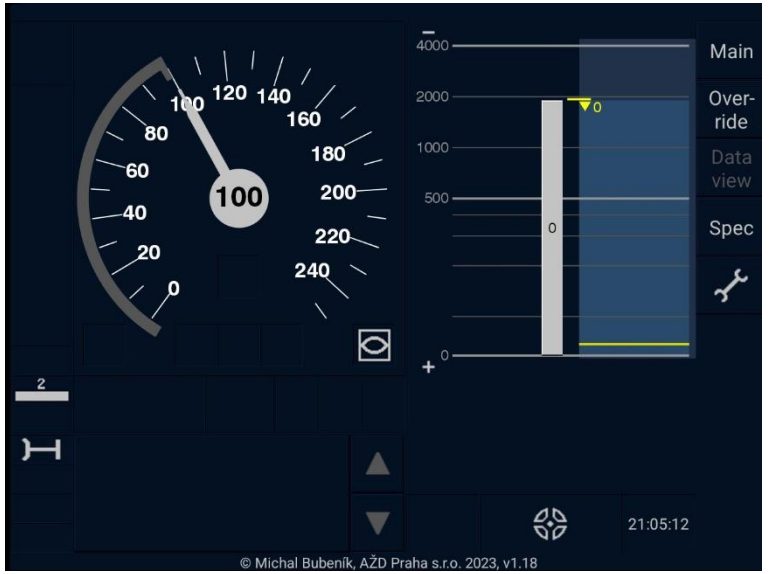
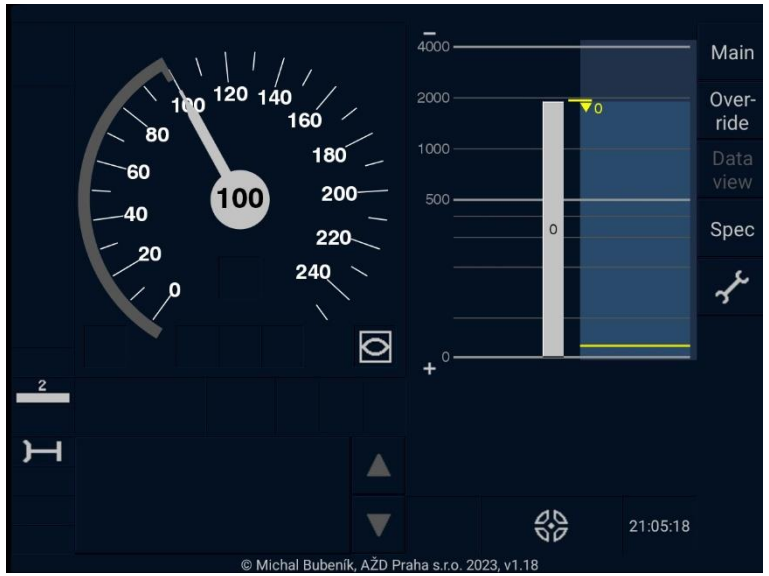
c) The train is approaching a target (EOA/SvL), d_{est} = 1,908 m, V_{est} = 100 km.h^{-1}, A_{est} = 0 m.s^{-2}		
		

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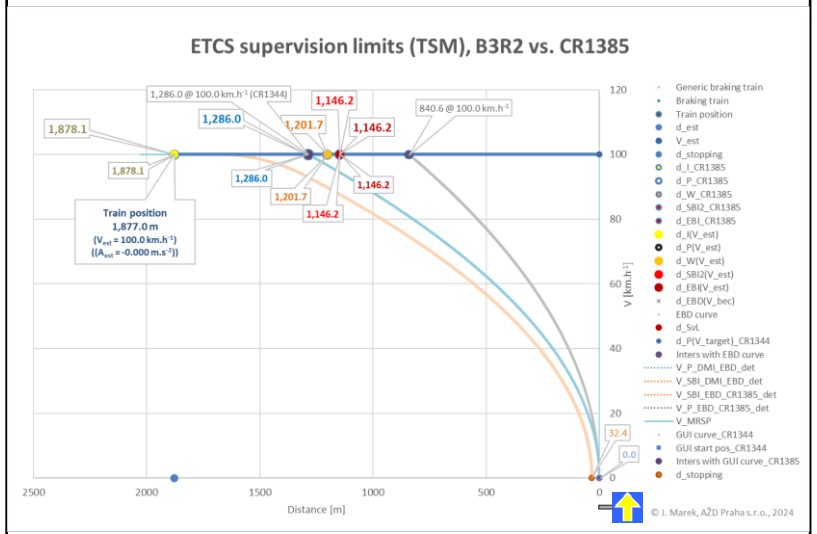
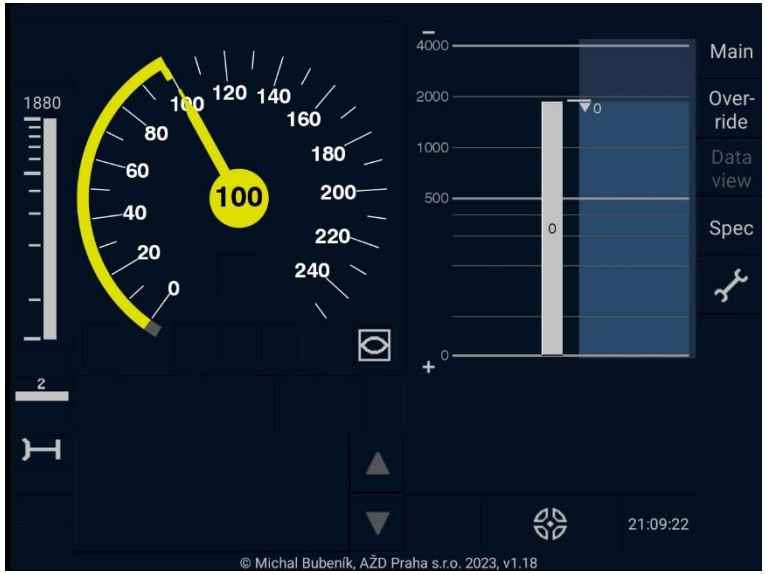
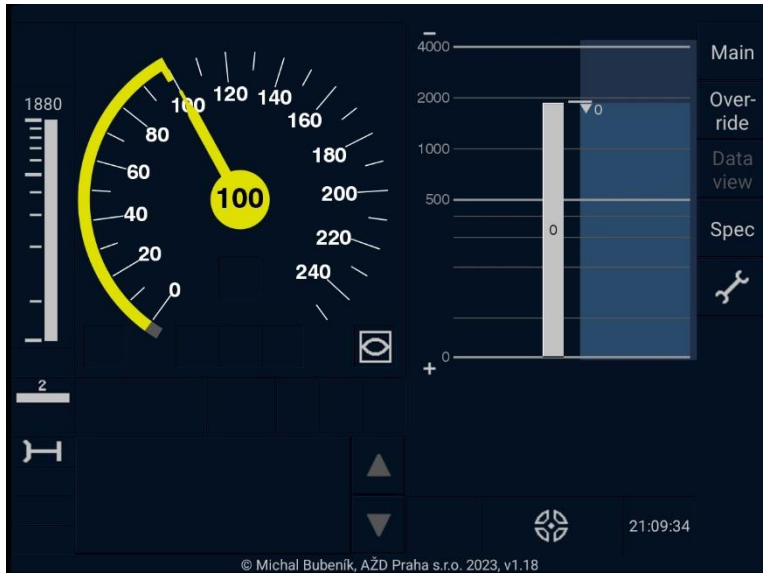
d) The train driver gets the first indication, d_{est} = 1,877 m, V_{est} = 100 km.h^{-1}, A_{est} = 0 m.s^{-2}		
		

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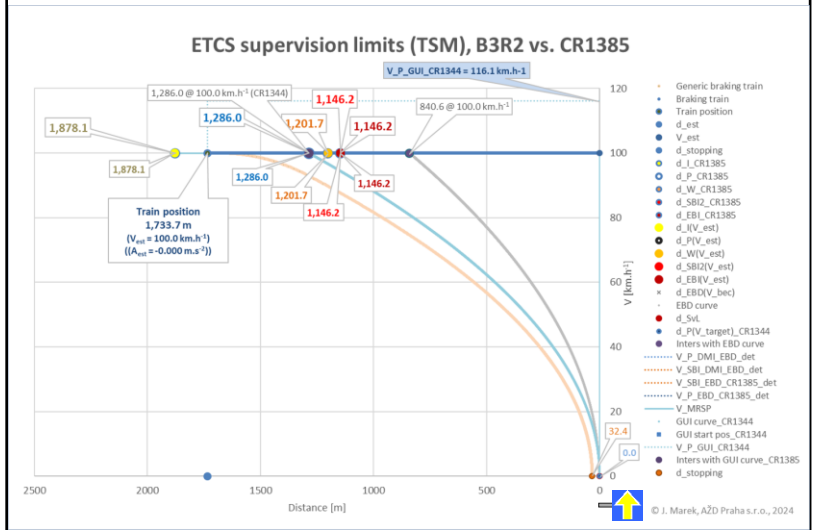
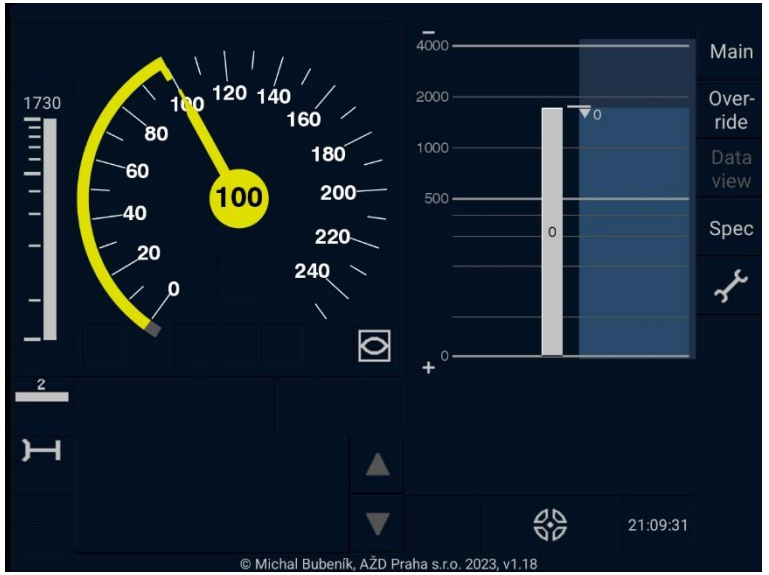
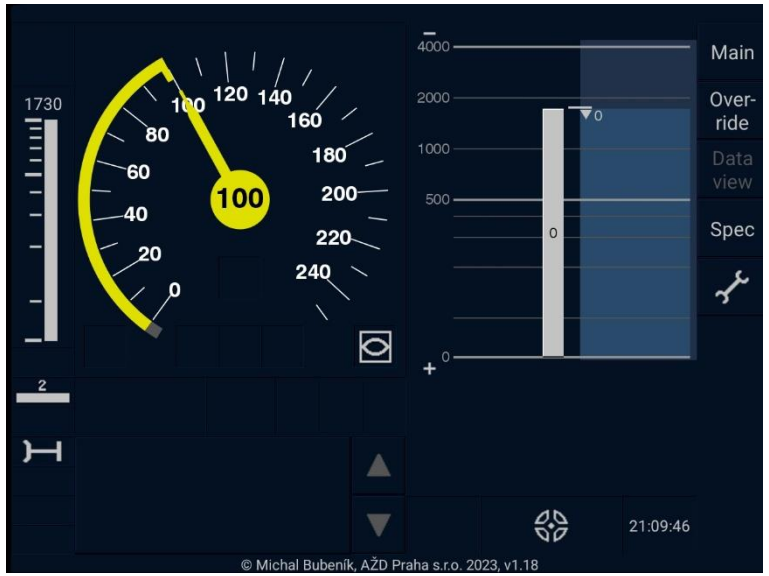
e) The train driver (ATO-OB) triggers the brake application, d_{est} = 1,734 m, V_{est} = 100 km.h^{-1}, A_{est} = -0.266 m.s^{-2}		
		

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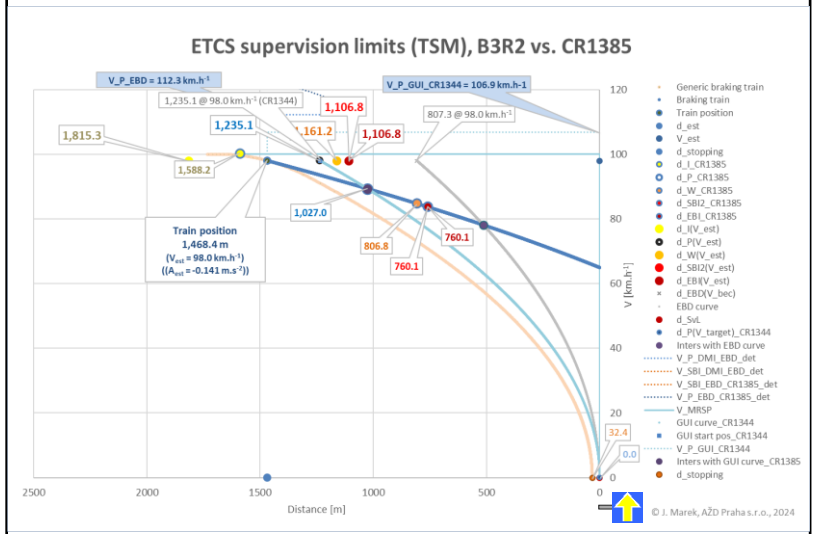
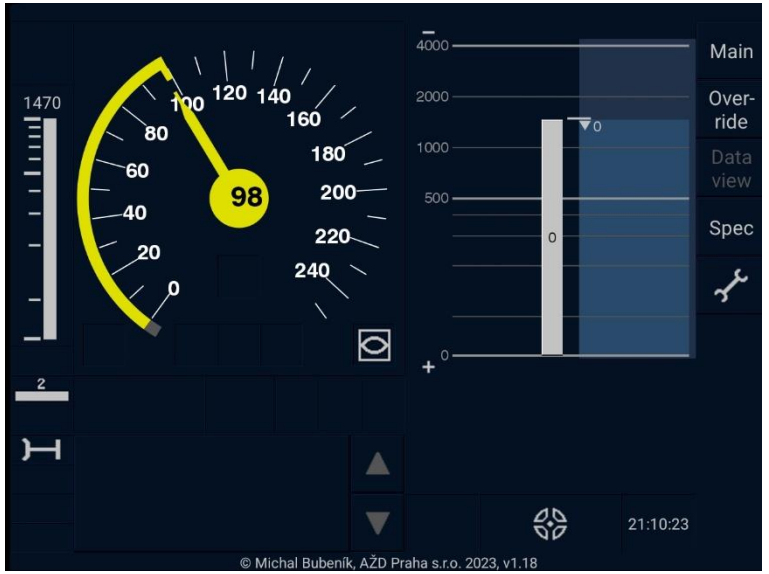
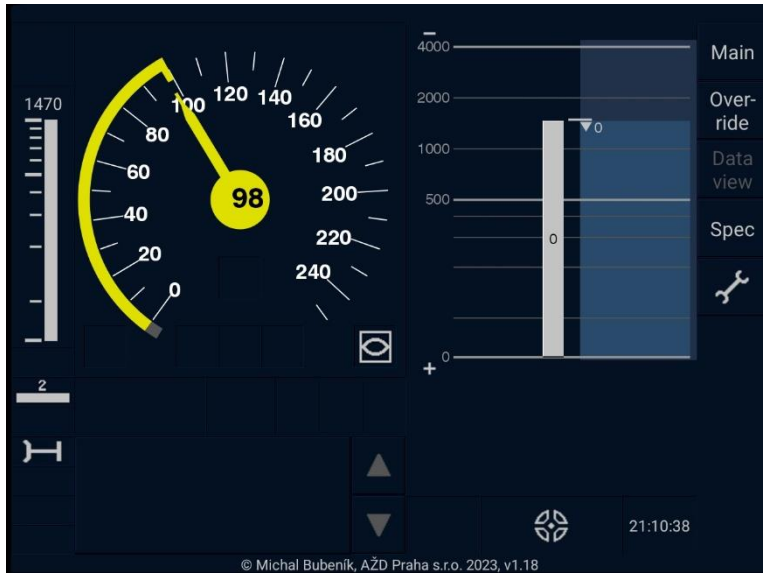
f) The brake is building-up (to 37 % of its full SB application), d_{est} = 1,468 m, V_{est} = 98 km.h^{-1}, A_{est} = -0.141 m.s^{-2}		
		

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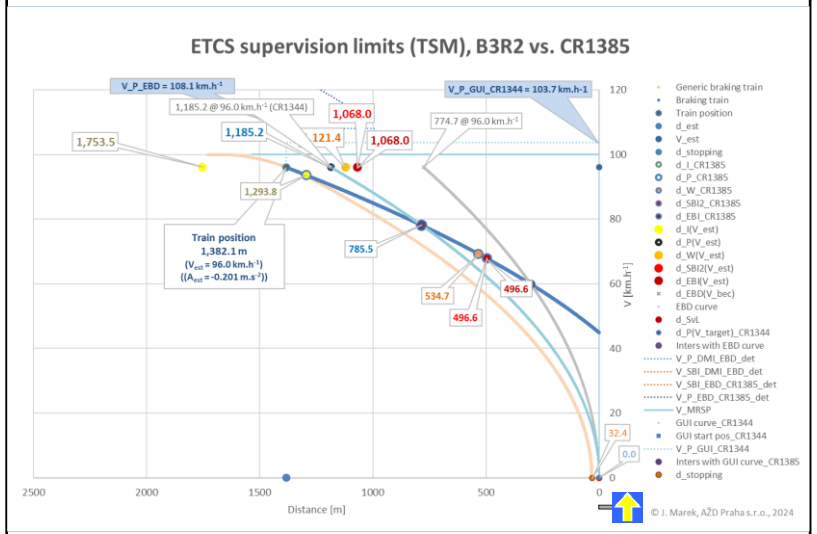
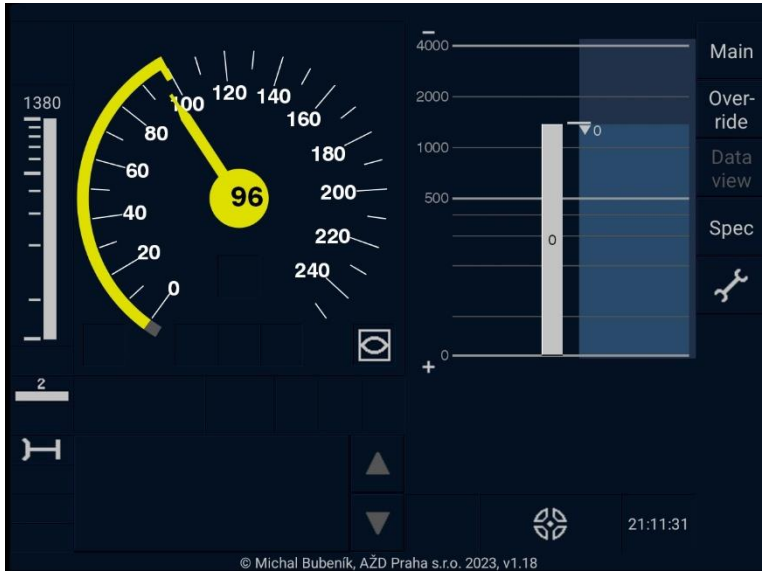
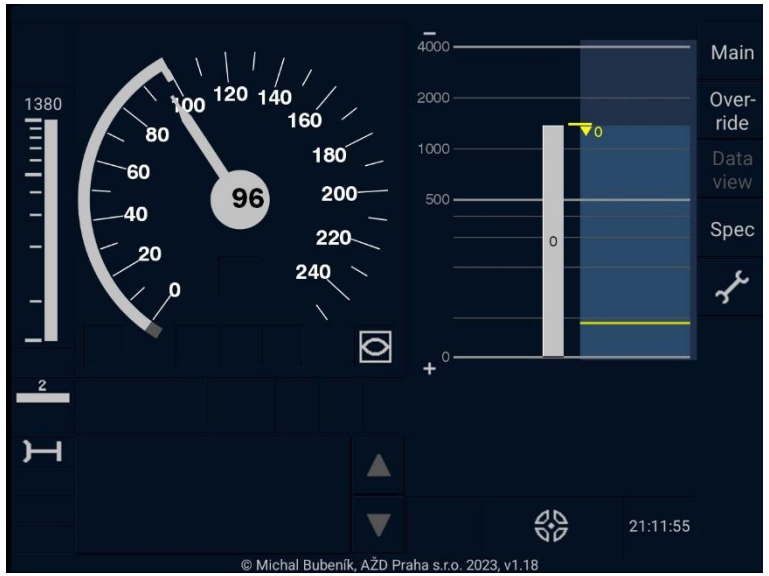
g) The brake is building-up (to 37 % of its full SB application), d_{est} = 1,382 m, V_{est} = 96 km.h^{-1}, A_{est} = -0.201 m.s^{-2}		
		

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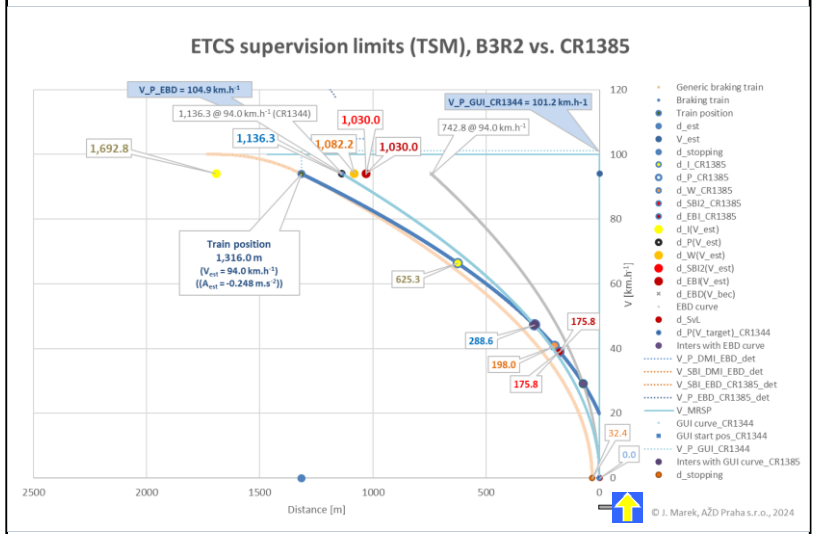
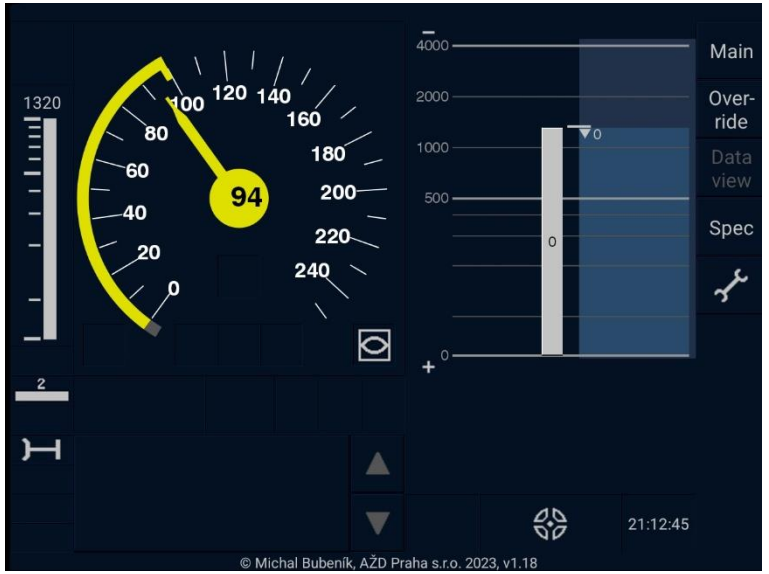
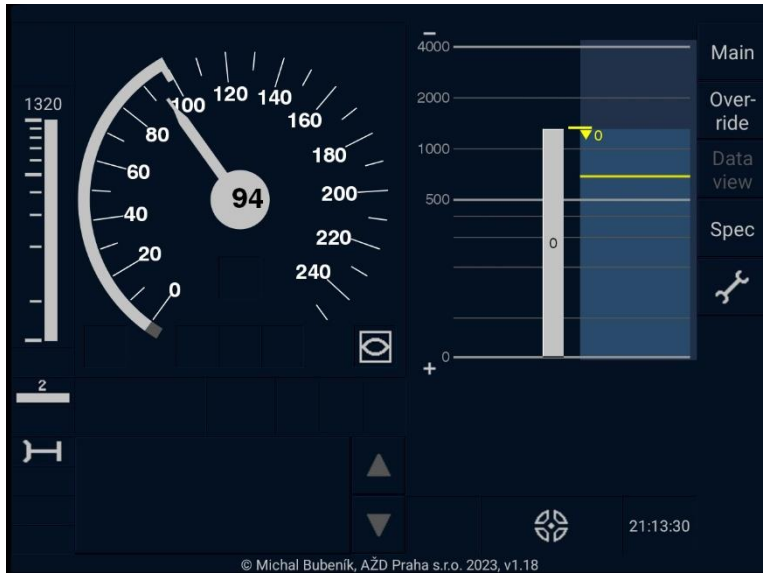
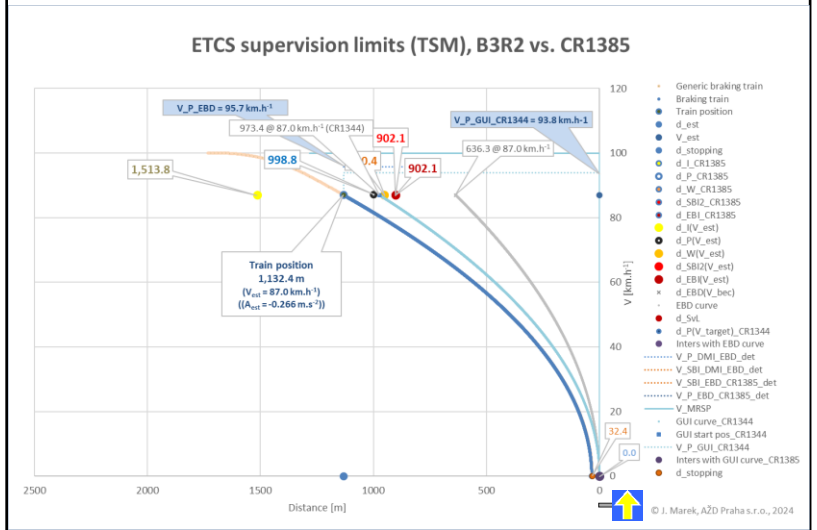
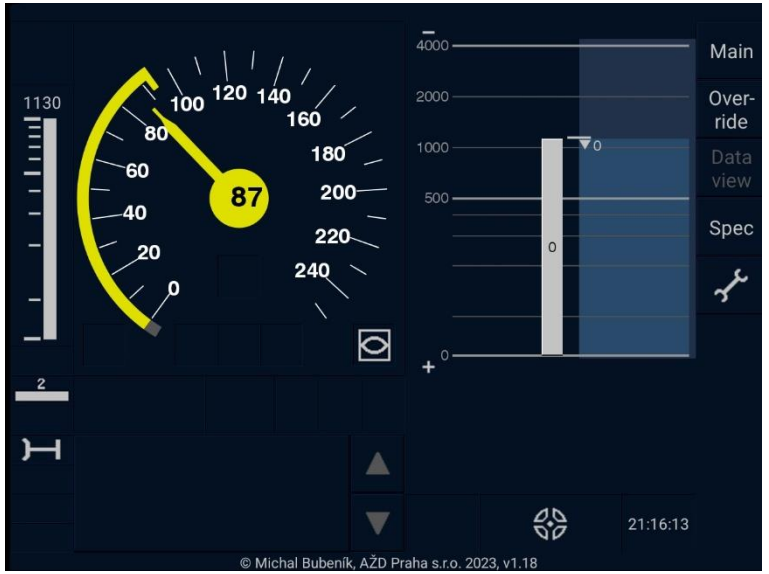
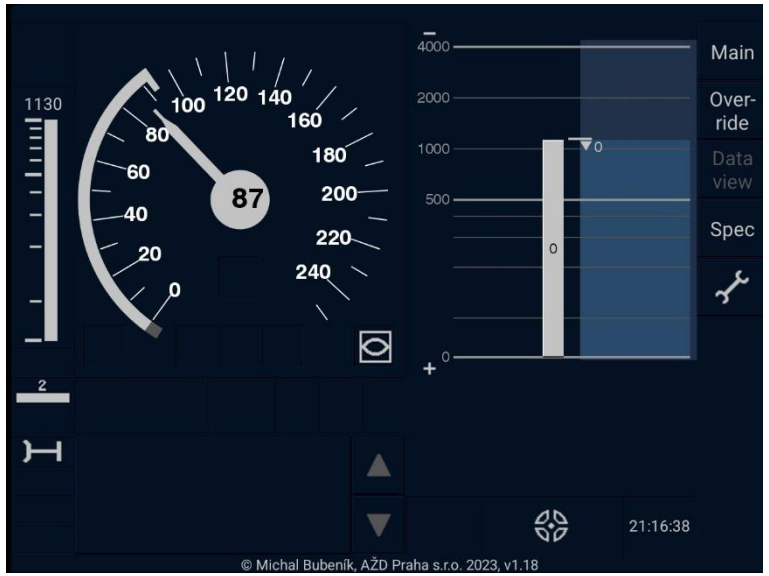
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
h) The brake is building-up (to 37 % of its full SB application), d_{est} = 1,316 m, V_{est} = 94 km.h^{-1}, A_{est} = -0.248 m.s^{-2}		
		

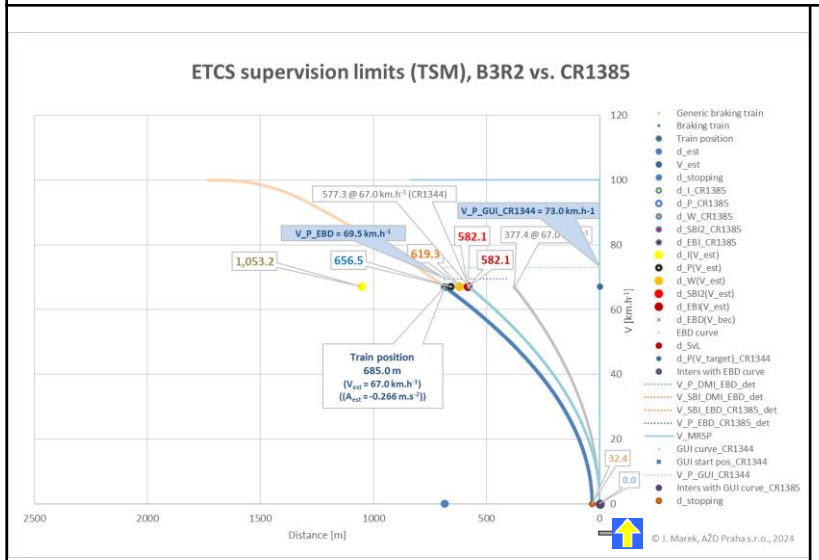
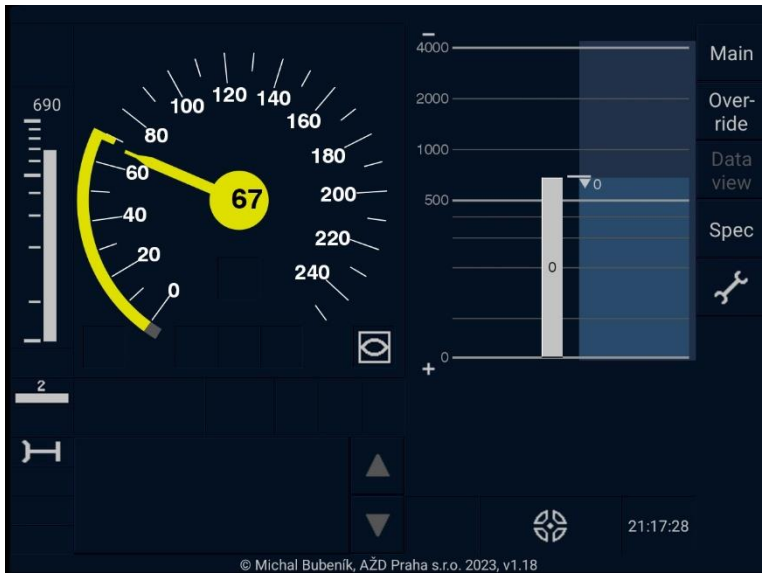
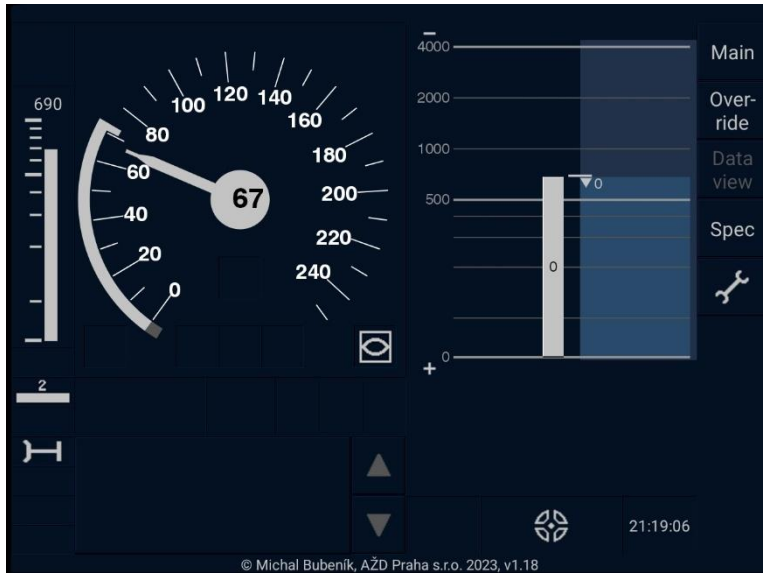
CR1385 (better handling with the measured decel.)

- Principle: For the trains braking enough (A_{est}), remove the ETCS BCs

Locations of the ETCS supervision limits acc. to [B3R2 SUBSET-026] vs. [CR1385]	Corresponding display on the DMI – calculations according to	
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
i) The brake has built-up to 37 % of its full SB application, d_{est} = 1,132 m, V_{est} = 87 km.h^{-1}, A_{est} = -0.266 m.s^{-2}		
		

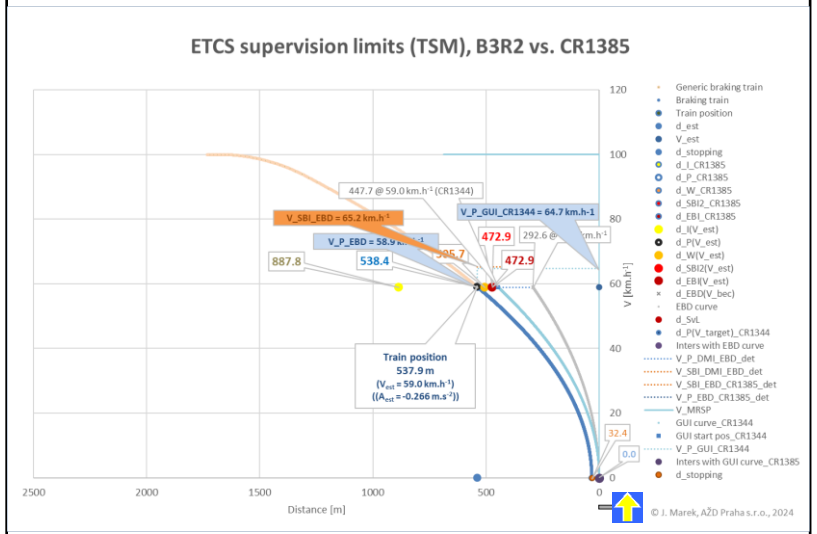
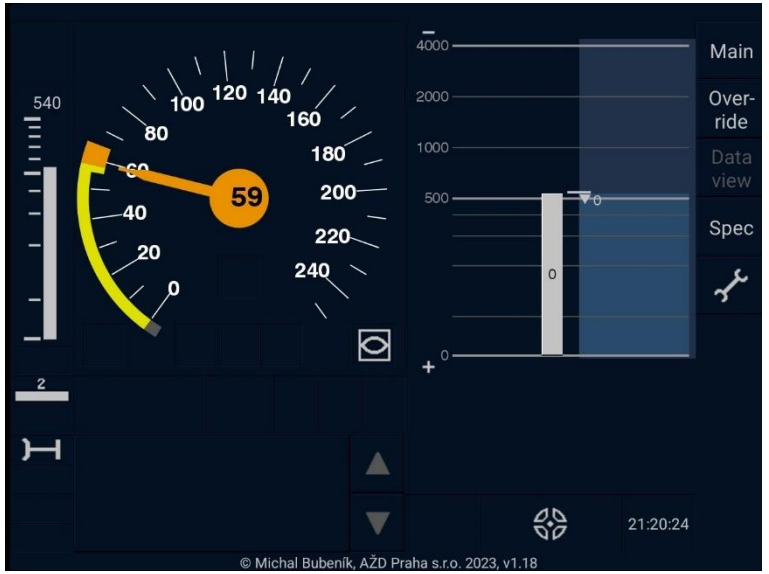
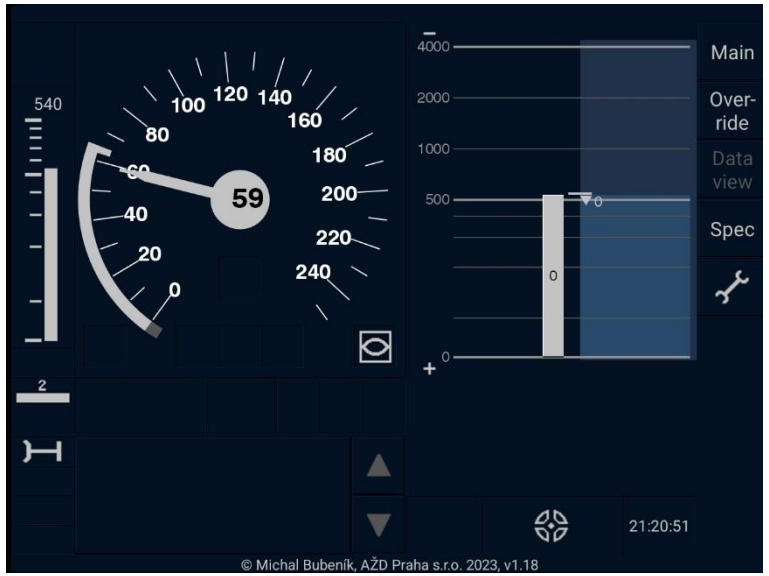
CR1385 (better handling with the measured decel.)

- Principle: For the trains braking enough (A_{est}), remove the ETCS BCs

Locations of the ETCS supervision limits acc. to [B3R2 SUBSET-026] vs. [CR1385]	Corresponding display on the DMI – calculations according to	
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
j) The train is braking to a stand with 37 % of its full SB application, d_{est} = 685 m, V_{est} = 67 km.h^{-1}, A_{est} = -0.266 m.s^{-2}		
		

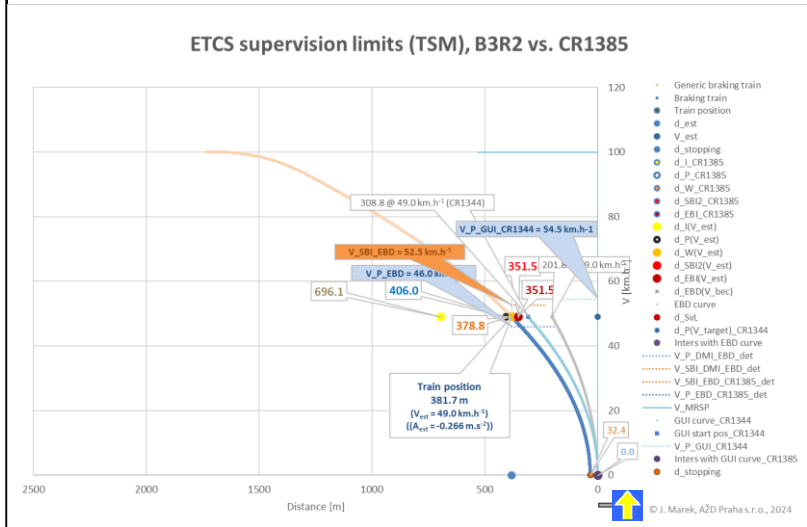
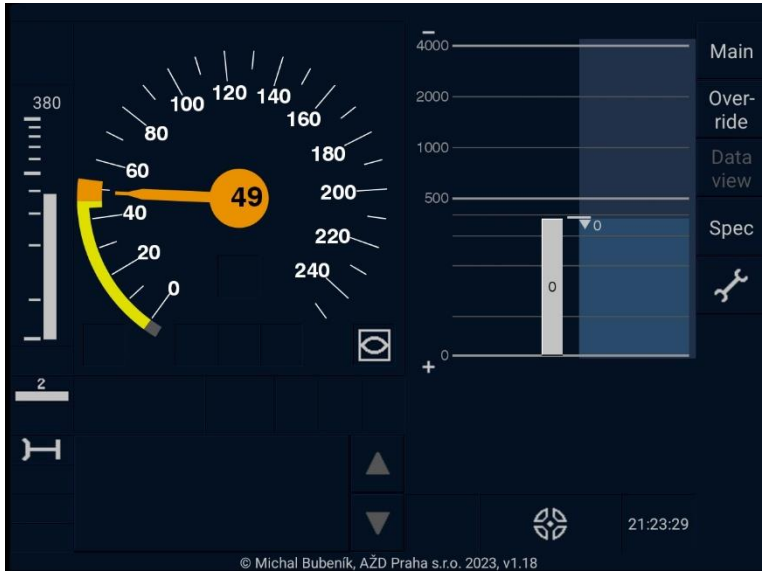
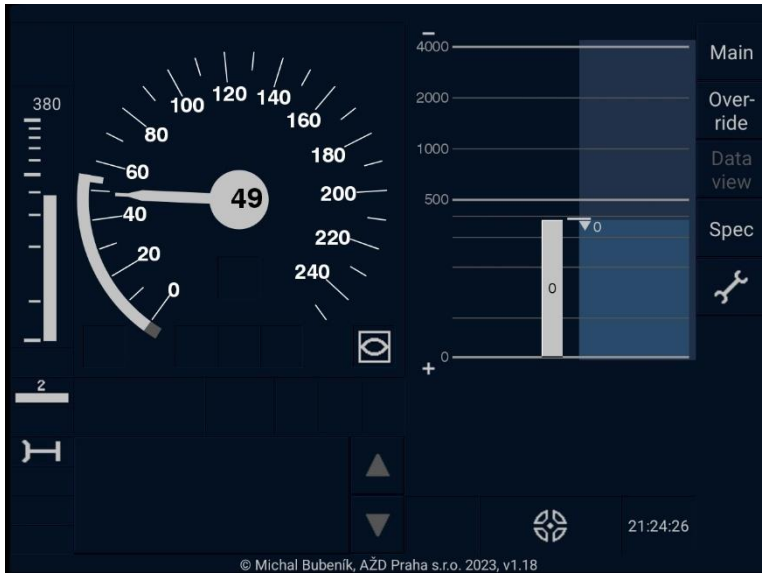
CR1385 (better handling with the measured decel.)

- Principle: For the trains braking enough (A_{est}), remove the ETCS BCs

Locations of the ETCS supervision limits acc. to [B3R2 SUBSET-026] vs. [CR1385]	Corresponding display on the DMI – calculations according to	
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
k) The train is braking to a stand with 37 % of its full SB application, d_{est} = 538 m, V_{est} = 59 km.h^{-1}, A_{est} = -0.266 m.s^{-2}		
		

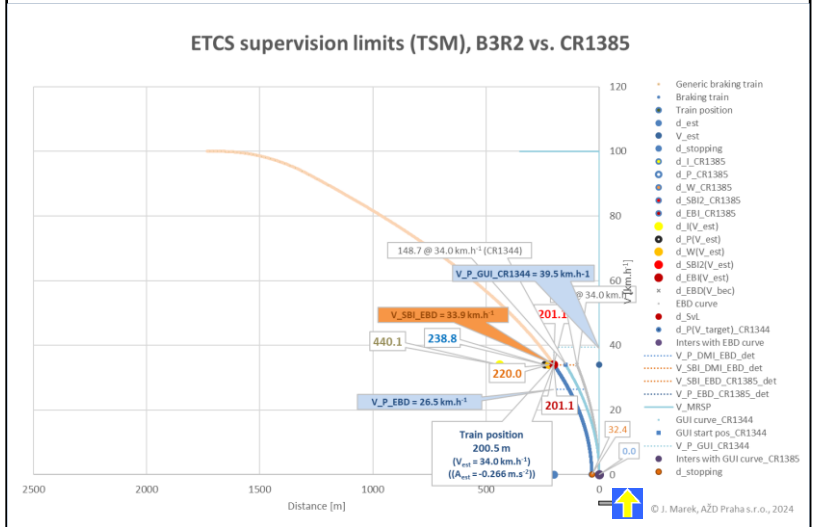
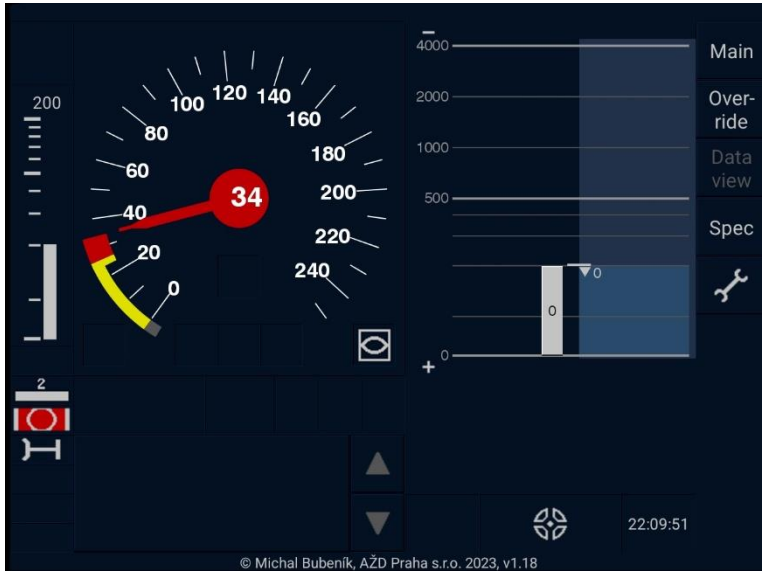
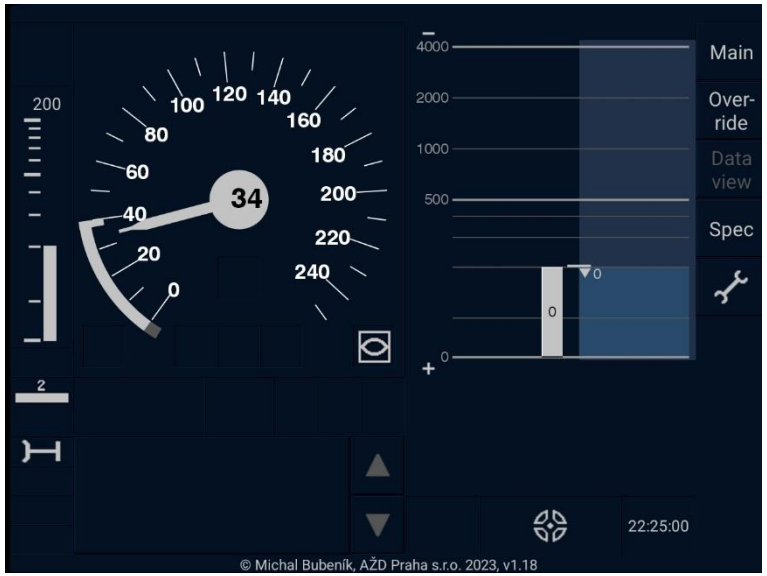
CR1385 (better handling with the measured decel.)

- Principle: For the trains braking enough (A_{est}), remove the ETCS BCs

Locations of the ETCS supervision limits acc. to [B3R2 SUBSET-026] vs. [CR1385]	Corresponding display on the DMI – calculations according to	
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
l) The train is braking to a stand with 37 % of its full SB application, d_{est} = 382 m, V_{est} = 49 km.h^{-1}, A_{est} = -0.266 m.s^{-2}		
		

CR1385 (better handling with the measured decel.)

- Principle: For the trains braking enough (A_{est}), remove the ETCS BCs

Locations of the ETCS supervision limits acc. to [B3R2 SUBSET-026] vs. [CR1385]	Corresponding display on the DMI – calculations according to	
	ETCS B3R2 SUBSET-026 & DMI	CR1385, orig. Marek, Myslivec, Bubeník, and Drápal (S+D (112) 3 and 6/2020)
m) The train is braking to a stand with 37 % of its full SB application, d_{est} = 201 m, V_{est} = 34 km.h^{-1}, A_{est} = -0.266 m.s^{-2}		
		

What did we find out?

- There are **two assumptions** in the ETCS BC computation **that can be removed**:
  - assumption of a constant (accelerating) train speed
  - assumption of a constant brake build-up time

SIGNAL+DRAHT (112) 3+6/2020

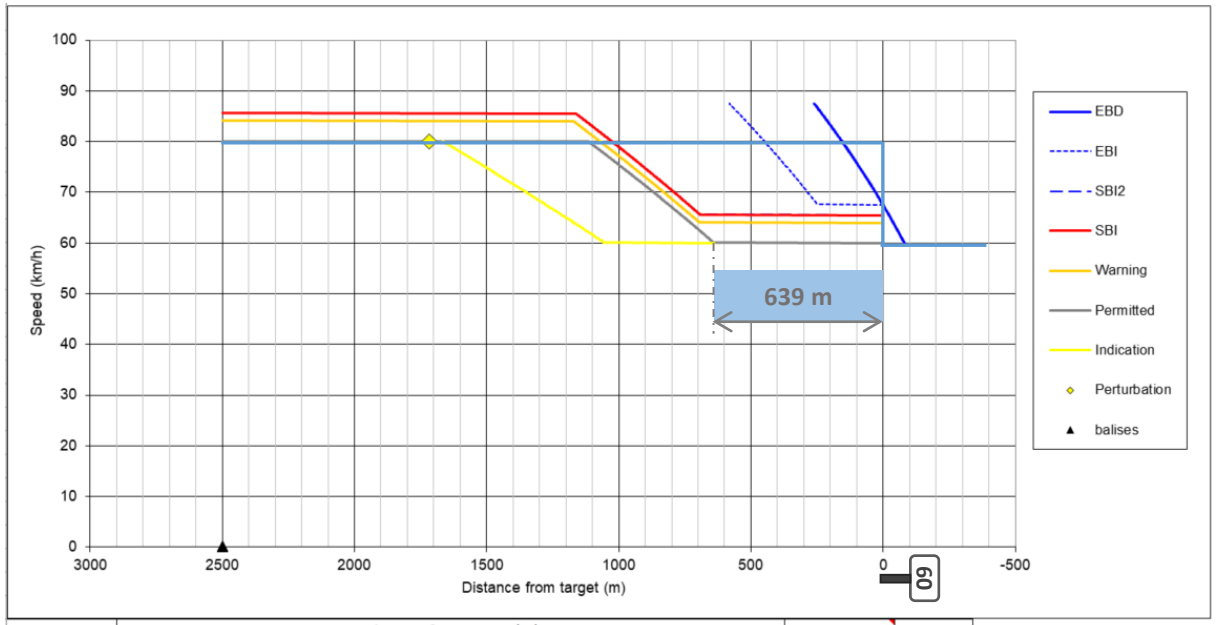
What did we find out?

- There are **two assumptions** in the ETCS BC computation **that can be removed**:
  - assumption of a constant (accelerating) train speed
  - assumption of a constant brake build-up time

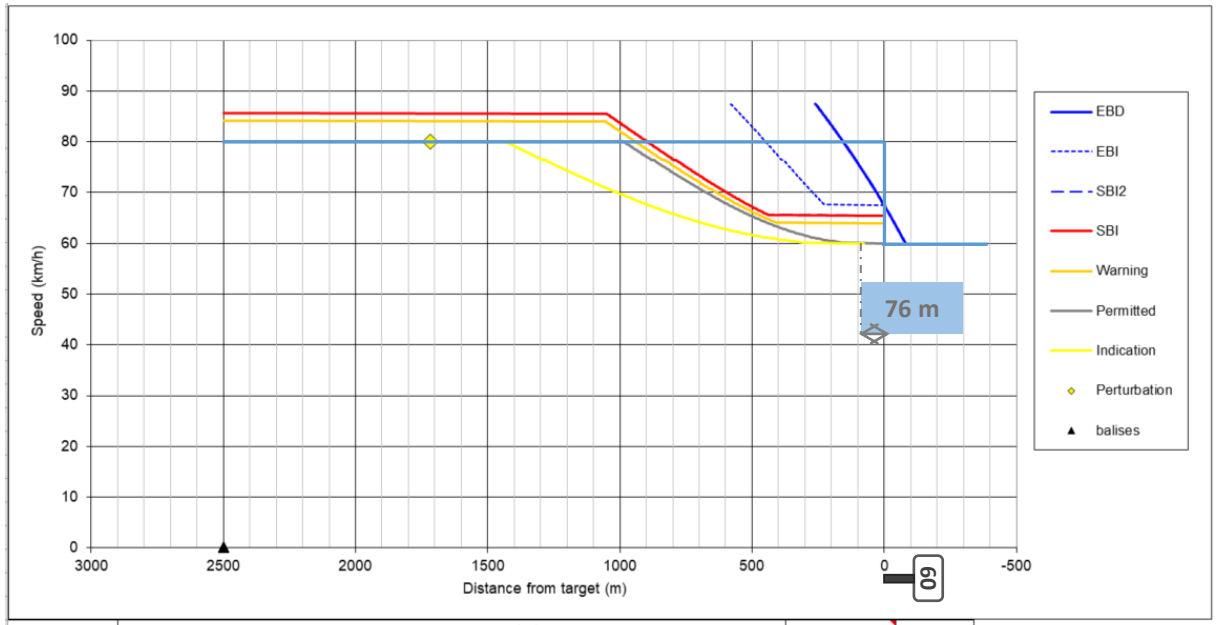
SIGNAL+DRAHT (112) 3+6/2020

CR1344 (optimalisation of the brake build-up time)

- Principle: consider actual ΔV (V_{est} vs. V_{target}), or even A_{est}
  - **previous** braking curves (**B3R2**) **vs.** – **optimised** braking curves (**B4R1**)



Initial speed (km/h)	Distance from target (m)							Release speed (km/h)	Journey time
	Perturbation	Indication	Permitted	Warning	SBI	EBI	StartRSM		
80.00	1717.25	1664.91	1114.33	1069.88	1025.44	448.31	N/A	N/A	125.23

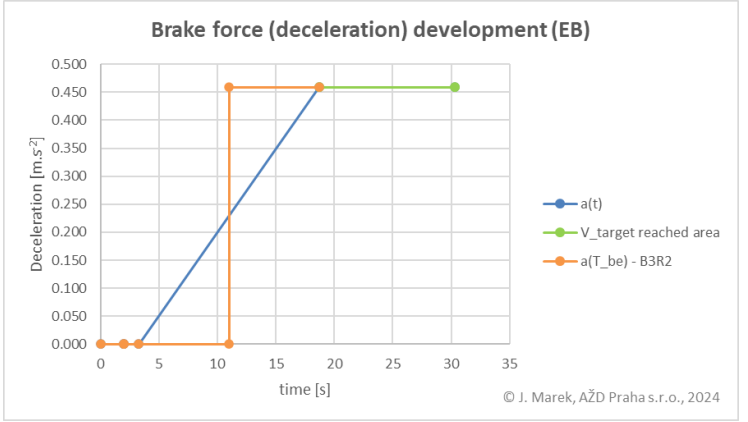


Initial speed (km/h)	Distance from target (m)							Release speed (km/h)	Journey time
	Perturbation	Indication	Permitted	Warning	SBI	EBI	StartRSM		
80.00	1717.25	1432.02	984.94	940.50	896.06	448.31	N/A	N/A	121.68

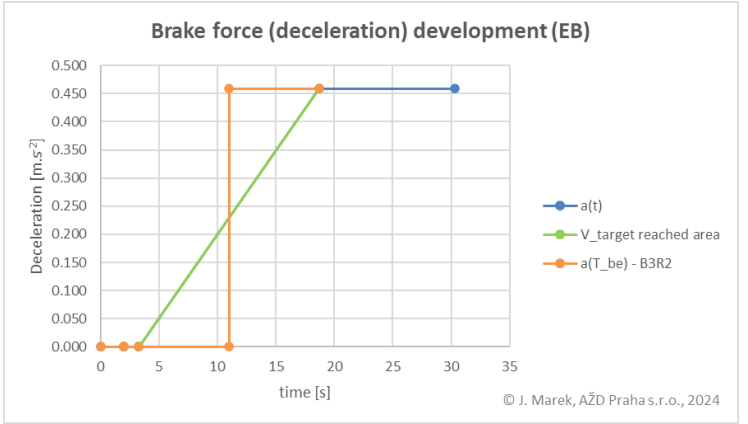
*) Freight train, 673 m, braked in P mode, 87 br.%, **SB in TSM allowed**

CR1344 (optimalisation of the brake build-up time)

- Principle: consider actual ΔV (V_{est} vs. V_{target}), or even A_{est}
  - When the optimisation is not needed?

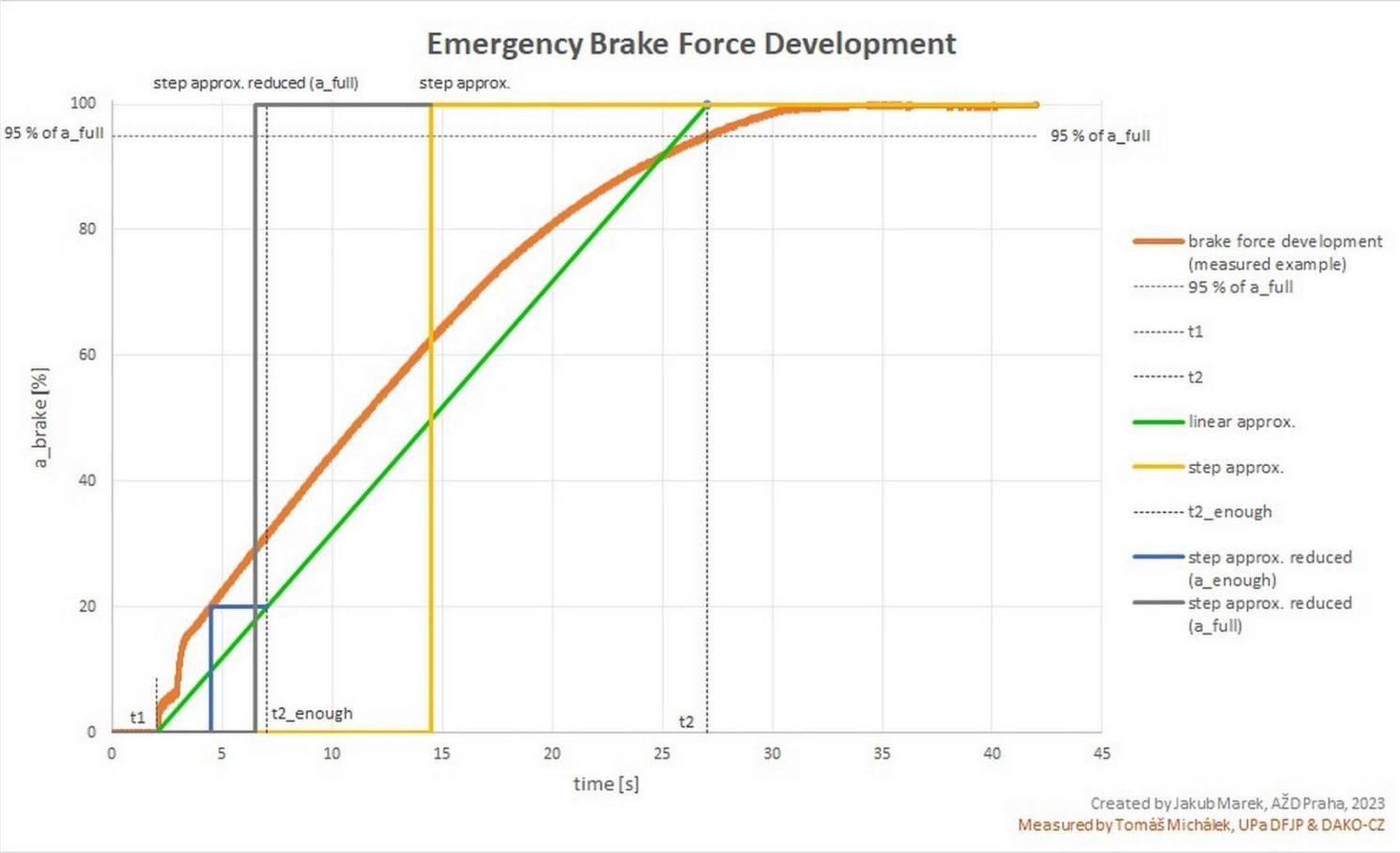


  - When the optimisation should be done?



CR1344 (optimalisation of the brake build-up time)

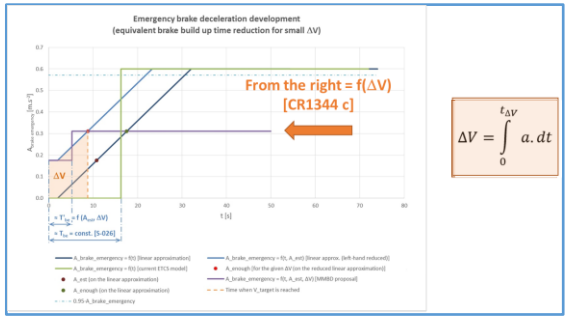
- Principle: consider actual ΔV (V_{est} vs. V_{target}), or even A_{est}



CR1344 (optimalisation of the brake build-up time)

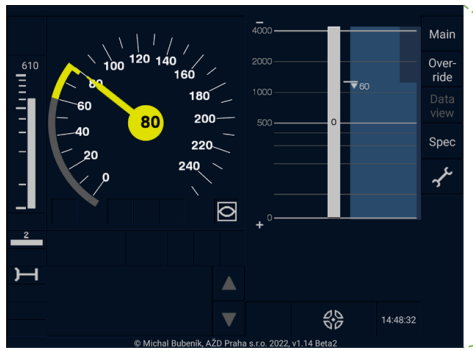
▪ Optimalisation of the brake build-up time (t_e) – B3R2 vs. B4R1:

- t_e computed **for every target individually** and is **f(V_{target}-V_{est})**
- uses **integration** of **a(t)**:

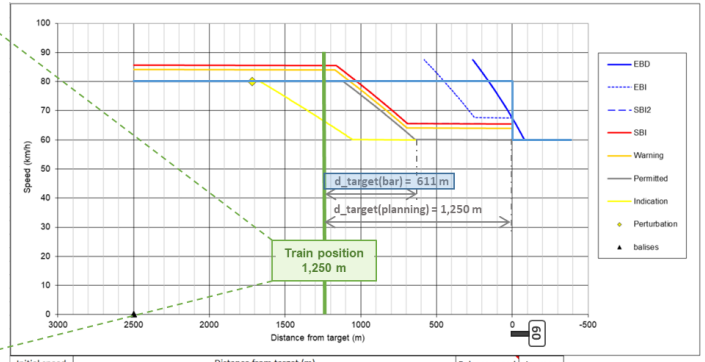


- **validated** against **UIC measu-rements** (> 4 000)
- **tested by train drivers** in NL (ProRail, NS)

- **B3R2-spec:**

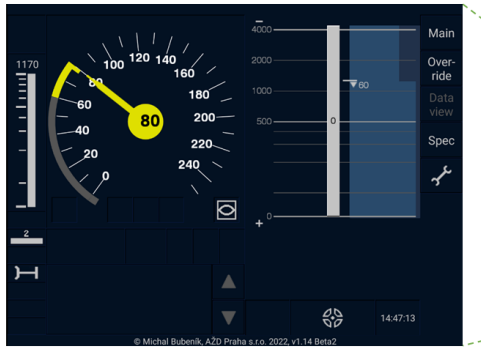


Freight train, 673 m, braked in P mode, 87 BWP; SB in TSM allowed

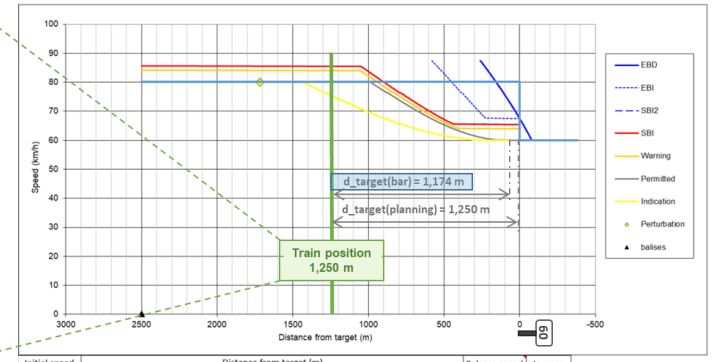


Initial speed (km/h)	Distance from target (m)							Release speed (km/h)	Journey time
	Perturbation	Indication	Permitted	Warning	SBI	EBI	StartRSM		
80.00	1717.25	1664.91	1114.33	1069.88	1025.44	448.31	N/A	N/A	125.23

- **B4R1-spec:**



Freight train, 673 m, braked in P mode, 87 BWP; SB in TSM allowed



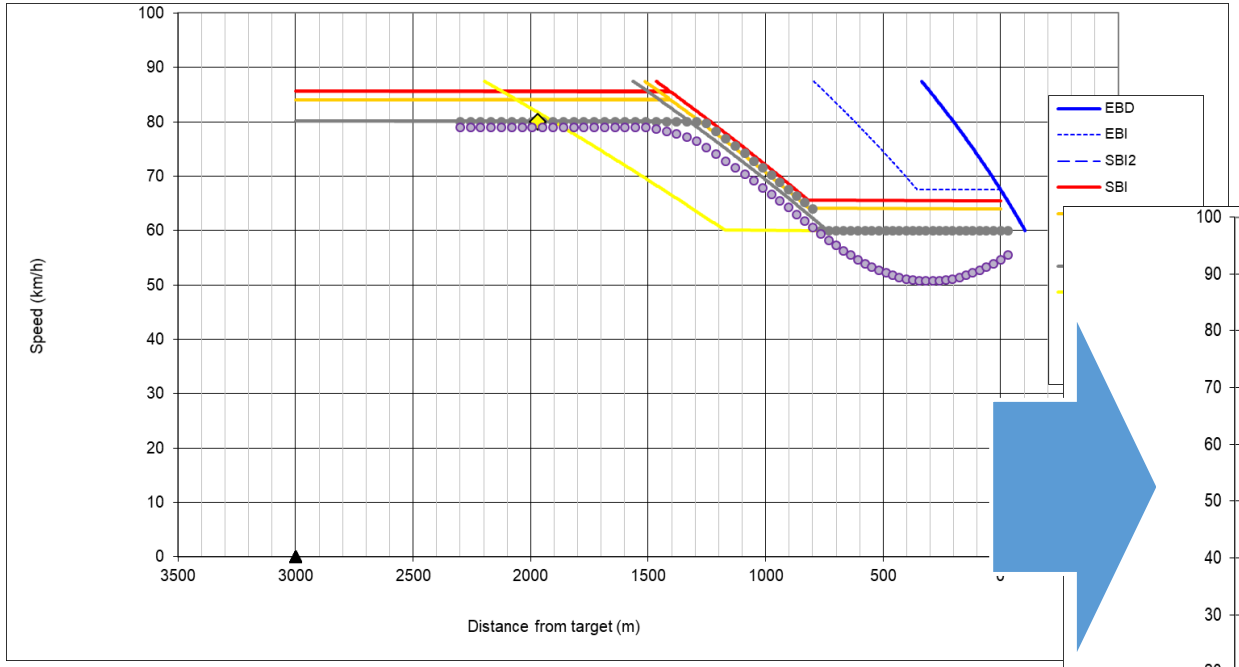
Initial speed (km/h)	Distance from target (m)							Release speed (km/h)	Journey time
	Perturbation	Indication	Permitted	Warning	SBI	EBI	StartRSM		
80.00	1717.25	1432.02	984.94	940.50	896.06	448.31	N/A	N/A	121.68

NEO Simulator

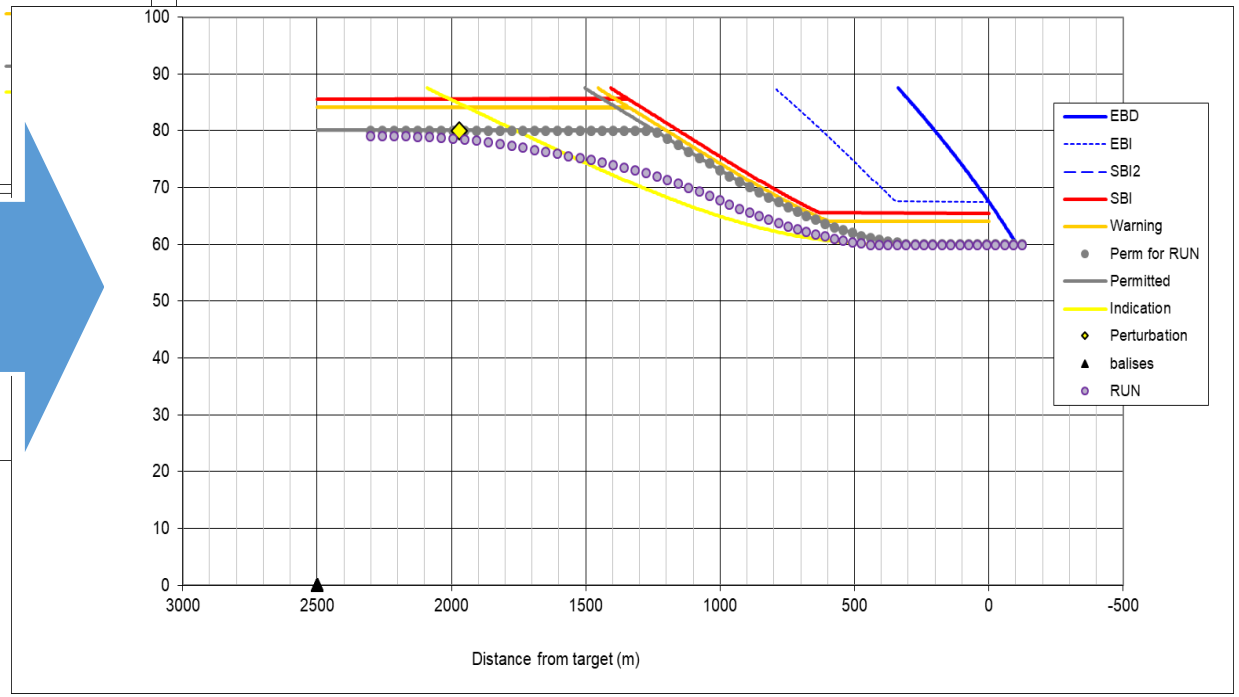
- **! enabler** for the future consideration of **deceleration** (CR1385)

CR1344 (optimalisation of the brake build-up time)

- **Optimalisation of the brake build-up time** (t_e) – benefits:



- ✓ **increased performance** – faster, longer
- ✓ **better driveability** – „P-curve“ can be better followed (which enables not undershooting V_{target})



Figures: © M. Bartholomeus, ProRail, based on the updated ERA BC sim tool v4.3, 2023

What did we find out?

- There are **two assumptions** in the ETCS BC computation **that can be removed**:
  - assumption of a constant (accelerating) train speed
  - assumption of a constant brake build-up time

SIGNAL+DRAHT (112) 3+6/2020

What did we find out?

- There are **two assumptions** in the ETCS BC computation **that can be removed**:
  - assumption of a constant (accelerating) train speed
  - assumption of a constant brake build-up time

CR discussion pending, to be resolved and packaged hopefully soon

ETCS CR1385

ETCS CR1344

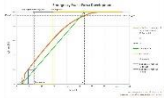
SIGNAL+DRAHT (112) 3+6/2020

CR packaged in CCS TSI 2023

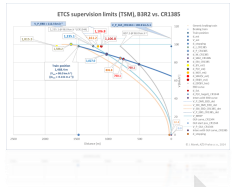
Where are we on this journey towards better ETCS?

S+D (112) 3+6/2020

UNISIG
Braking curves
Task Force



NOW



European Commission

EC mandate to work on CR1385 (?)

2018 •the story •begins

2020 •S+D •publ.

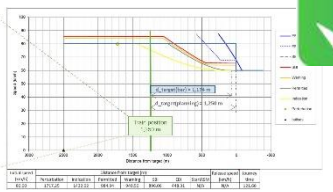
2020 •U BC TF •launched

2023 •CR1344 •solved

2027? •CR1385 •solved?

ERTMS USERS GROUP

ETCS OBU Baseline 4 Release 1 (full envelope) implements CR1344 [CCS TSI (EU) 2023/1695]



ETCS Braking curves: Conclusions

- Some **B3R2 assumptions** that **can be removed**, updated **to** allow:
  - improved **performance** (allowing trains run faster for longer)
  - better **driveability** (no undershooting of the target speed)
  - improved **safety** (removing the use of release speed)

✓ **Already in CCS TSI 2023**

✓ **Pending official EU discussion**

- Those assumptions are:
  - assumption of a constant brake build-up time (**CR1344**)
  - assumption of a constant train speed (**CR1385**)
  - … (see e.g. ERTMS 2024 Conference WS #10b presentations)

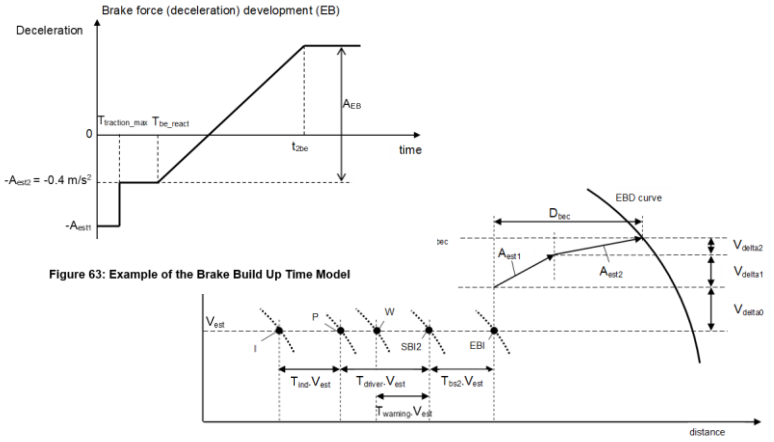
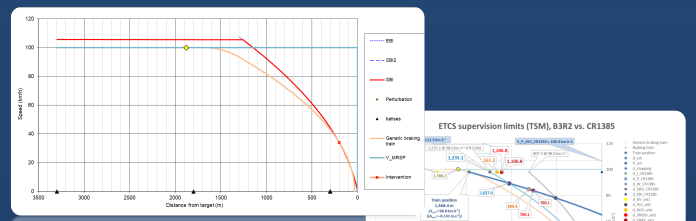


Figure 63: Example of the Brake Build Up Time Model

Figure 45: Braking to target supervision limits from EBD curve

Thank you for your attention!



J. Marek

marek.jakub@azd.cz