The using of GNSS local-elements as a model of the GNSS/GALILEO certification.

by

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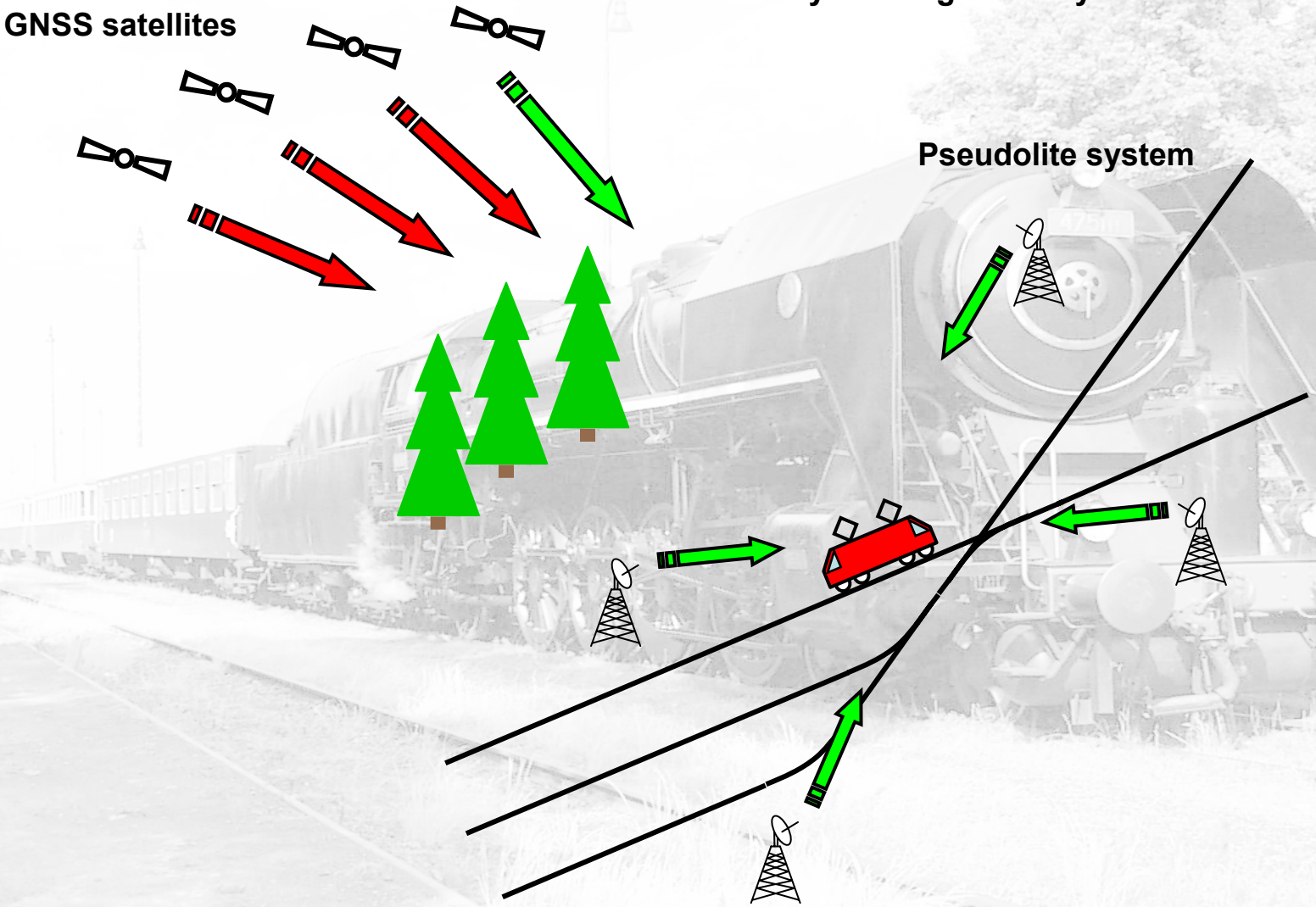
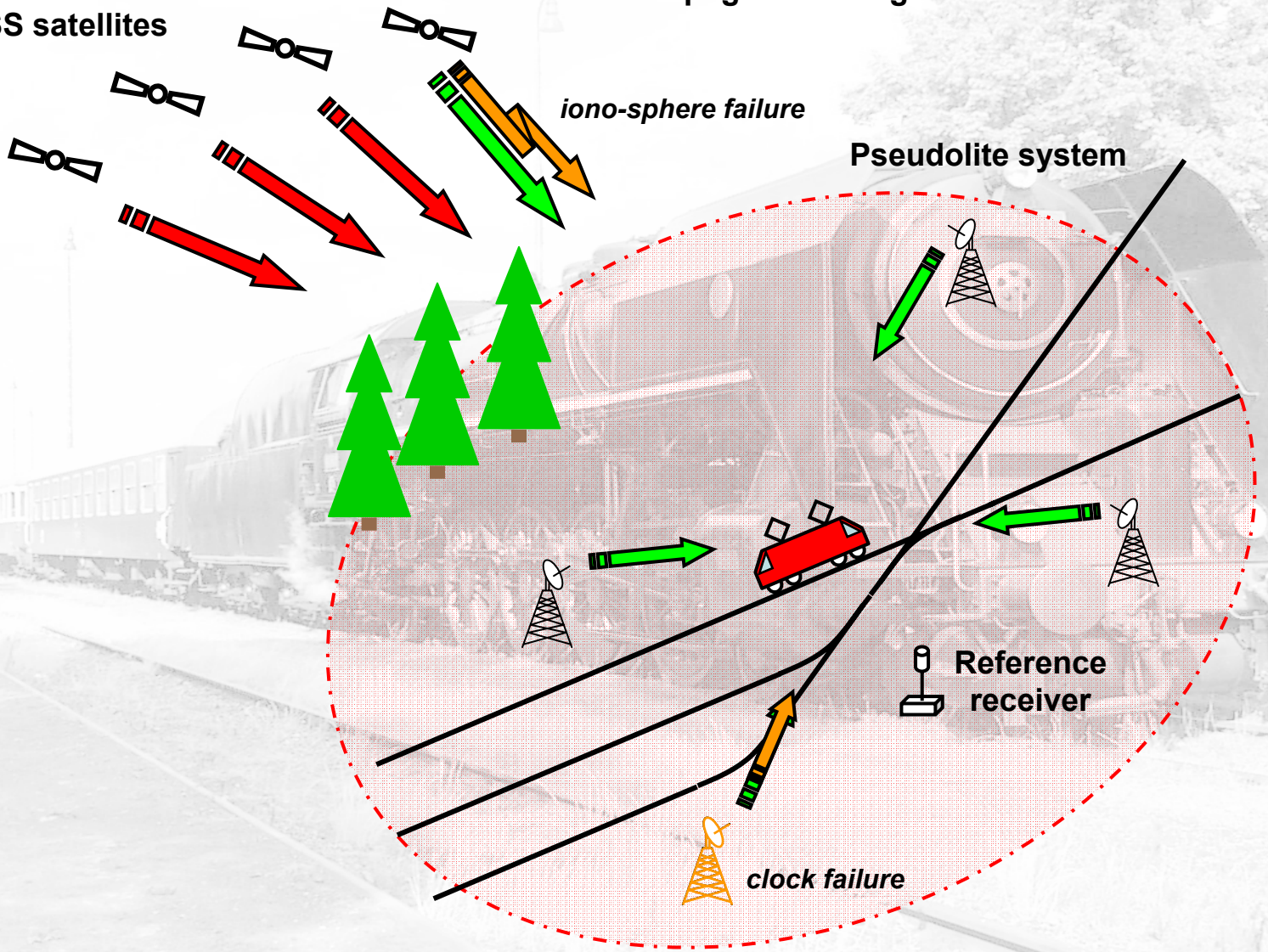
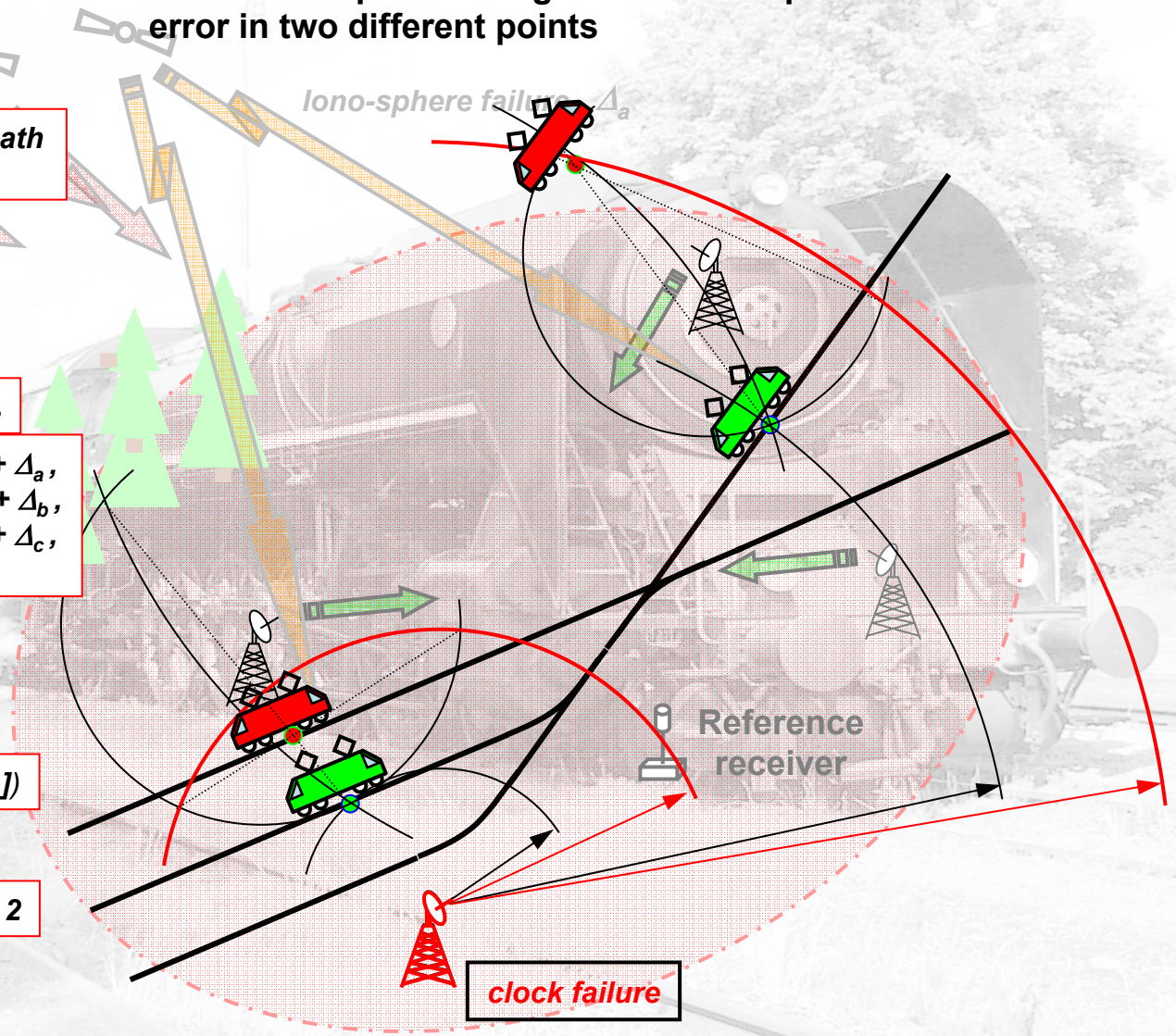
Availability of navigations systems.



Propagation of signal failures.



Different influence of measured pseudorange error on the position error in two different points



failure of trasmitters or signal path in given time

signal failure

$[X,Y,Z]_1$

$a1 = a1_{TRUE} + \Delta_a$,
$b1 = b1_{TRUE} + \Delta_b$,
$c1 = c1_{TRUE} + \Delta_c$,
...

$[X,Y,Z]_2$

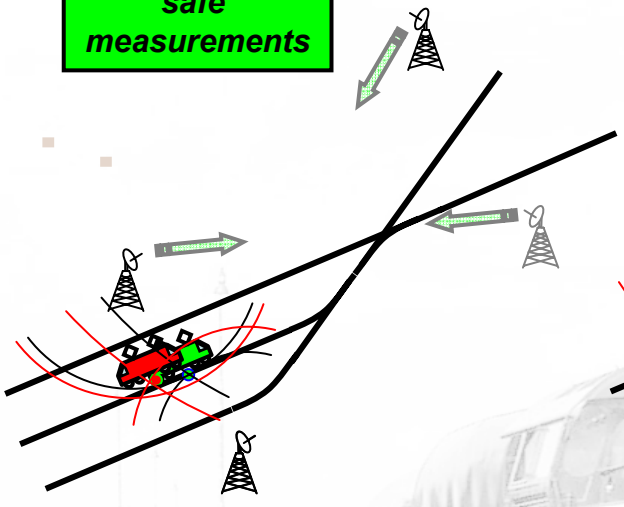
$a2 = a2_{TRUE} + \Delta_a$,
$b2 = b2_{TRUE} + \Delta_b$,
$c2 = c2_{TRUE} + \Delta_c$,
...

$\Delta_a, \Delta_b, \Delta_c, \ldots \approx$ const. in whole area

Pos. Error = φ ([X,Y,Z] , [a,b,c,...])

Pos. Error 1 $\neq$ Pos. Error 2

safe measurements

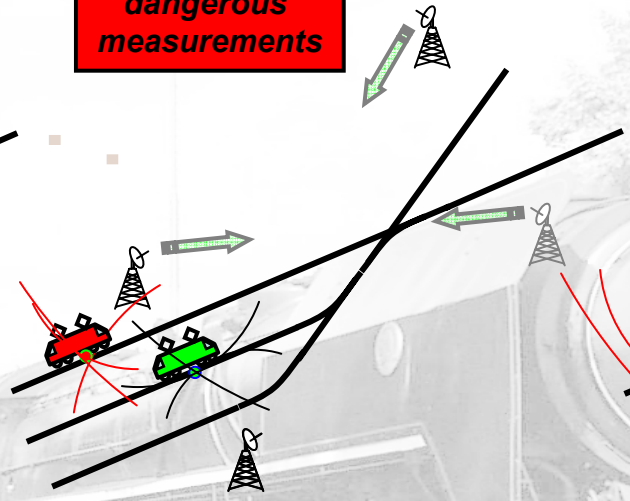


transmitter or path failure

pseudorange measurementserror $[\Delta_a, \Delta_b, \Delta_c]$

position error $\Delta_{XY} < APE$

dangerous measurements

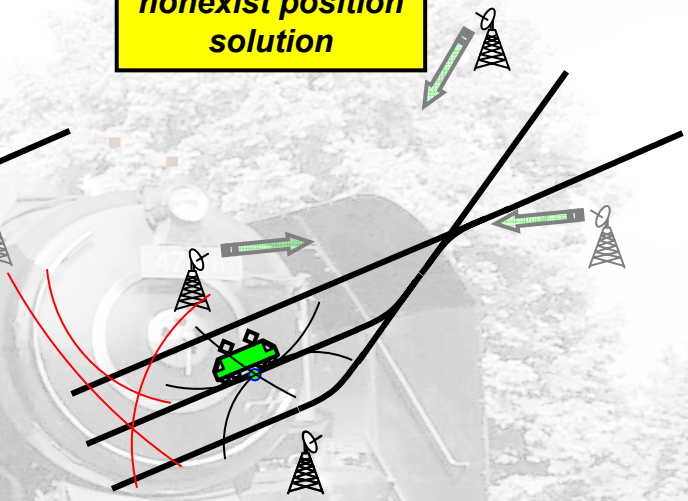


transmitter or path failure

pseudorange measurementserror $[\Delta_a, \Delta_b, \Delta_c]$

position error $\Delta_{XY} > APE$

nonexist position solution



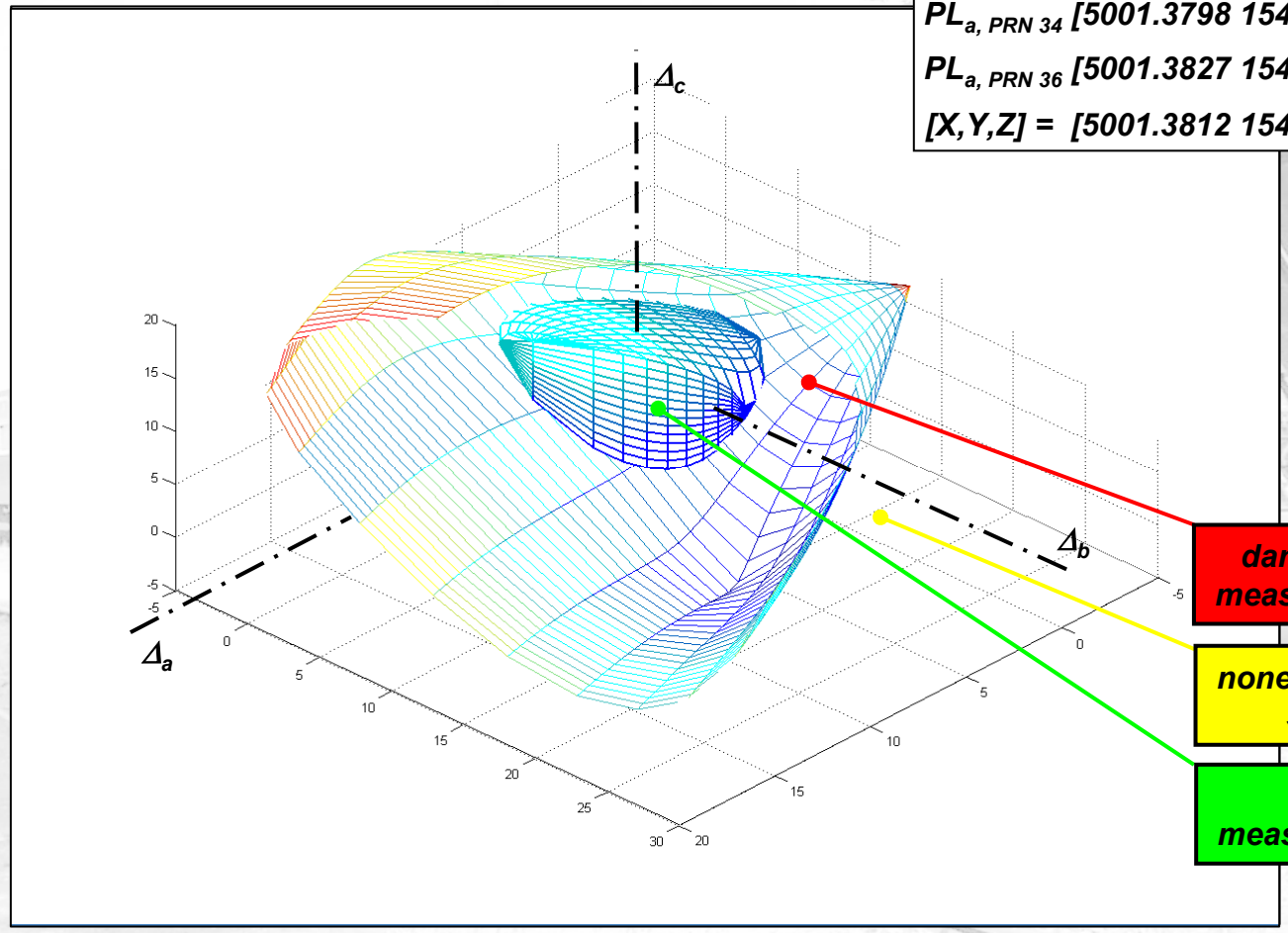
transmitter or path failure

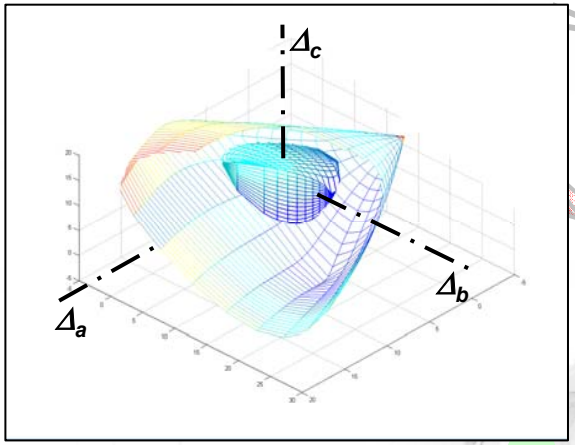
pseudorange measurementserror $[\Delta_a, \Delta_b, \Delta_c]$

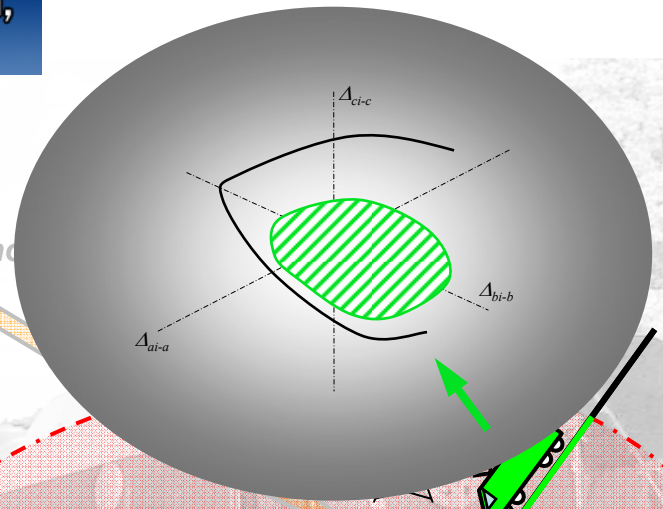
position solution doesn'e exist

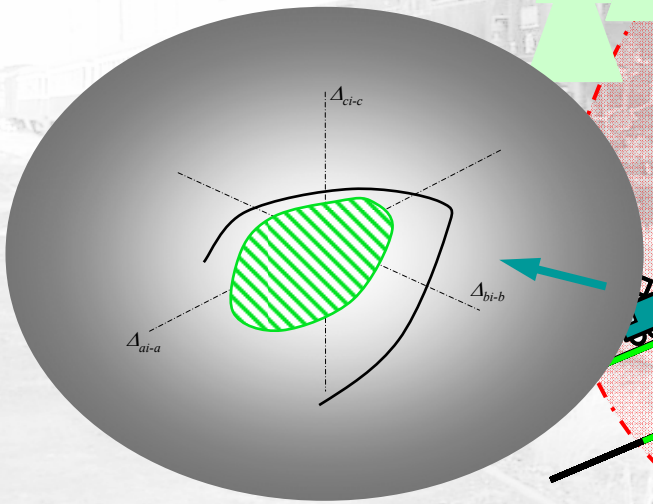
Safe and dangerous error-areas for measurements of three pseudoranges in the given point.

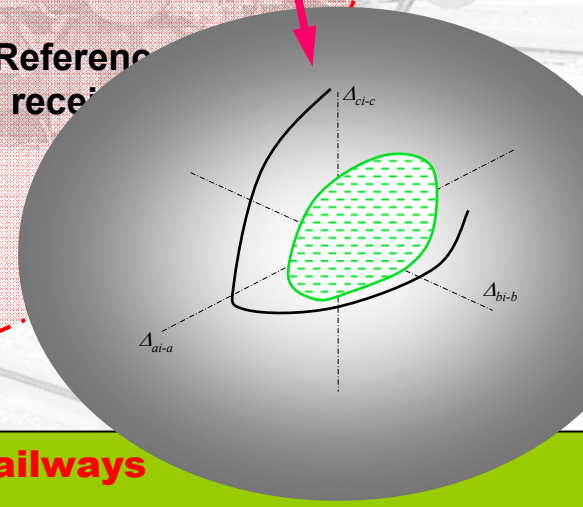
$PL_{a,\ PRN\ 33}$ [5001.3864 1547.9670 270.6034]
$PL_{a,\ PRN\ 34}$ [5001.3798 1547.9692 270.5348]
$PL_{a,\ PRN\ 36}$ [5001.3827 1547.9797 270.3298]
[X,Y,Z] = [5001.3812 1547.9744 269.0000]

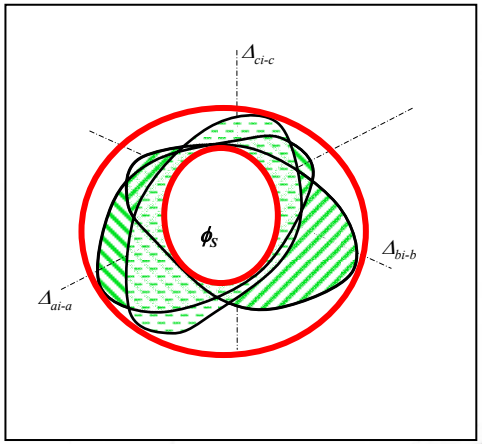



Δ_c
Δ_a
Δ_b


Δ_{ci-c}
Δ_{bi-b}
Δ_{ai-a}


Δ_{ci-c}
Δ_{bi-b}
Δ_{ai-a}


Δ_{ci-c}
Δ_{bi-b}
Δ_{ai-a}


$\Delta_{ci\text{-}c}$
ϕ_S
$\Delta_{bi\text{-}b}$
$\Delta_{ai\text{-}a}$

$\Delta_{ci\text{-}c}$
$\Delta_{bi\text{-}b}$
$\Delta_{ai\text{-}a}$
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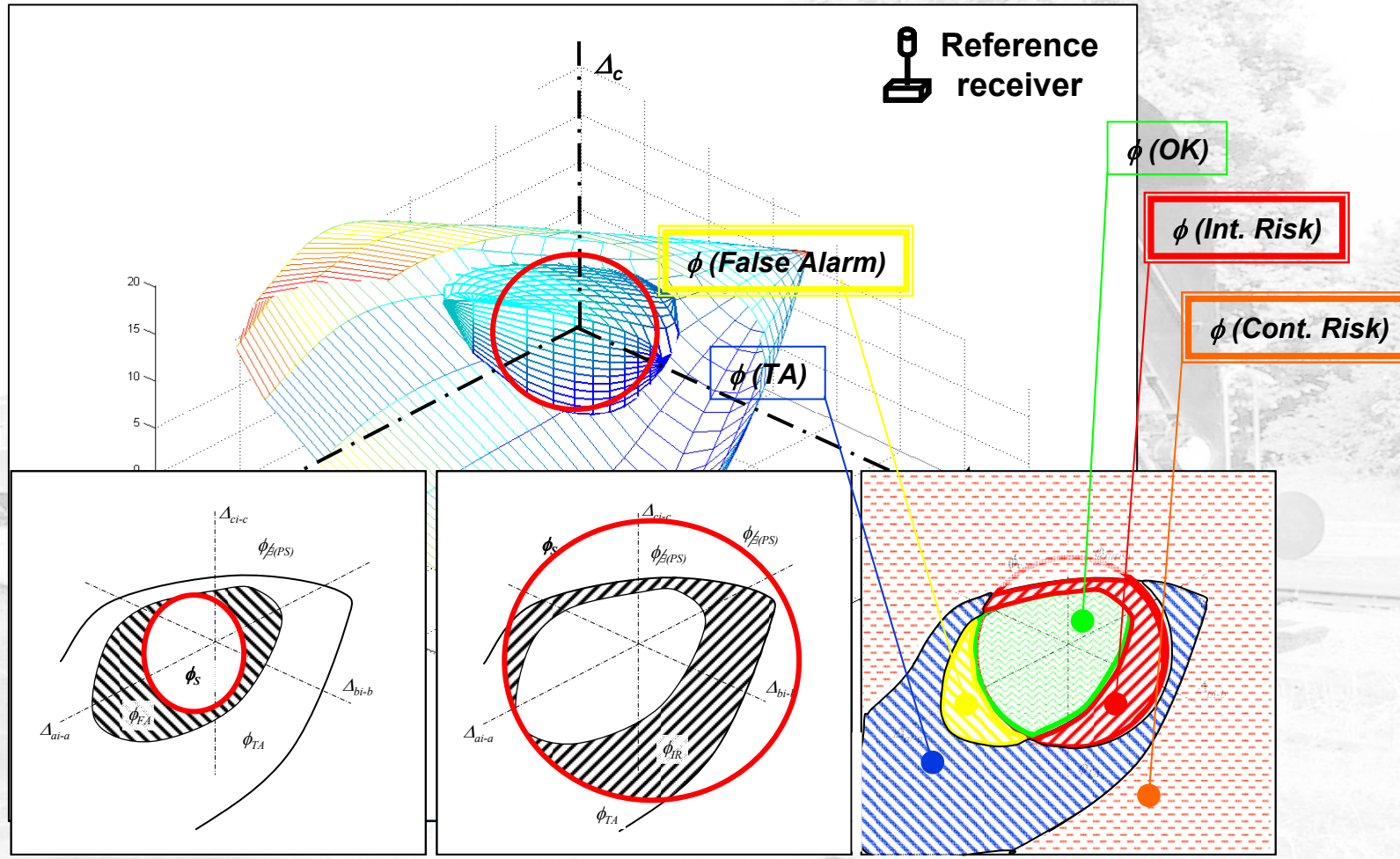
Safe and dangerous error-areas for measurements of three pseudoranges in the given point.



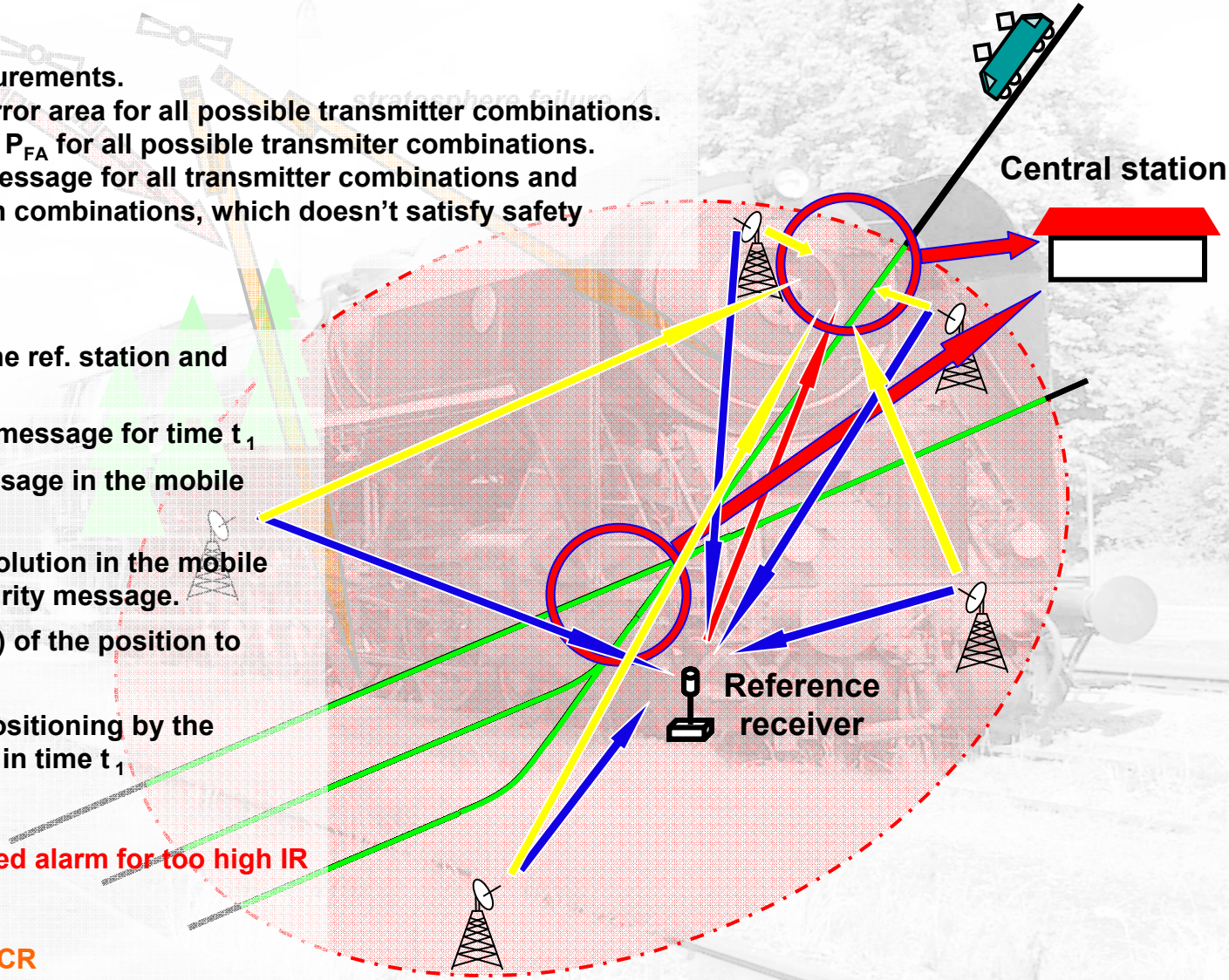
Simplified scenario of the safe positioning by the pseudolite system

Reference station
- monitores all signal measurements.
- defines the optimal safe error area for all possible transmitter combinations.
- determines the IR, CR and P_{FA} for all possible transmiter combinations.
- determines the integrity message for all transmitter combinations and procliams the alarm for such combinations, which doesn't satisfy safety requirements.

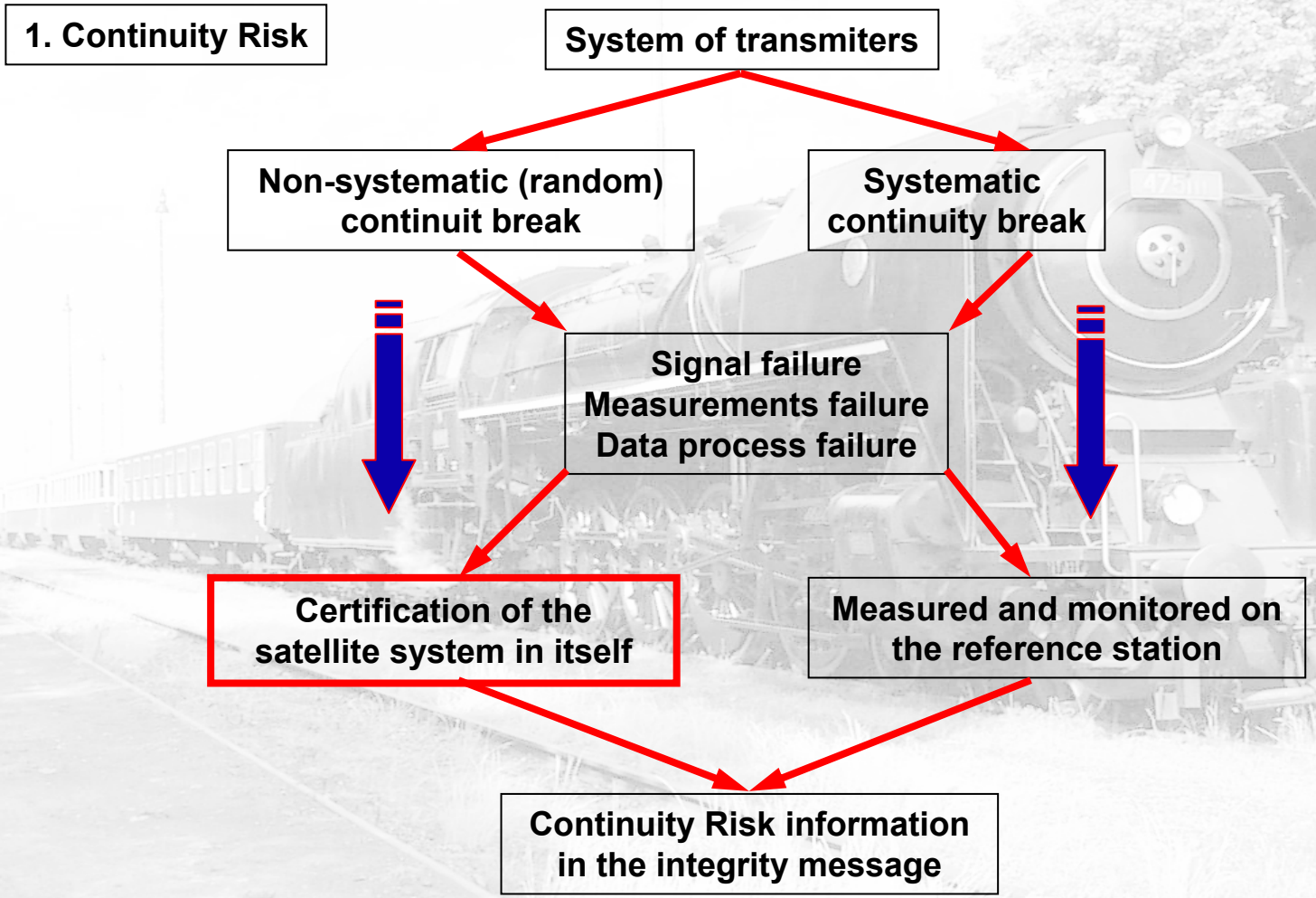
Basic operations in time t_1

1. signal measurements in the ref. station and mobile receiver.
2. Transmission of integrity message for time t_1
3. Receiving of integrity message in the mobile receiver
4. Choice optimal position solution in the mobile receiver about relevant integrity message.
5. Sending (*if it's neccessity*) of the position to central station

The Integrity message for positioning by the combination of transmitters in time t_1
- IM(33,34,35,36,37)
- IM(33,34,35,36)
- IM(33,34,35,37) – proclaimed alarm for too high IR
- IM(33,34,36,37)
- IM(33,35,36,37)
- IM(34,35,36,37) – too high CR



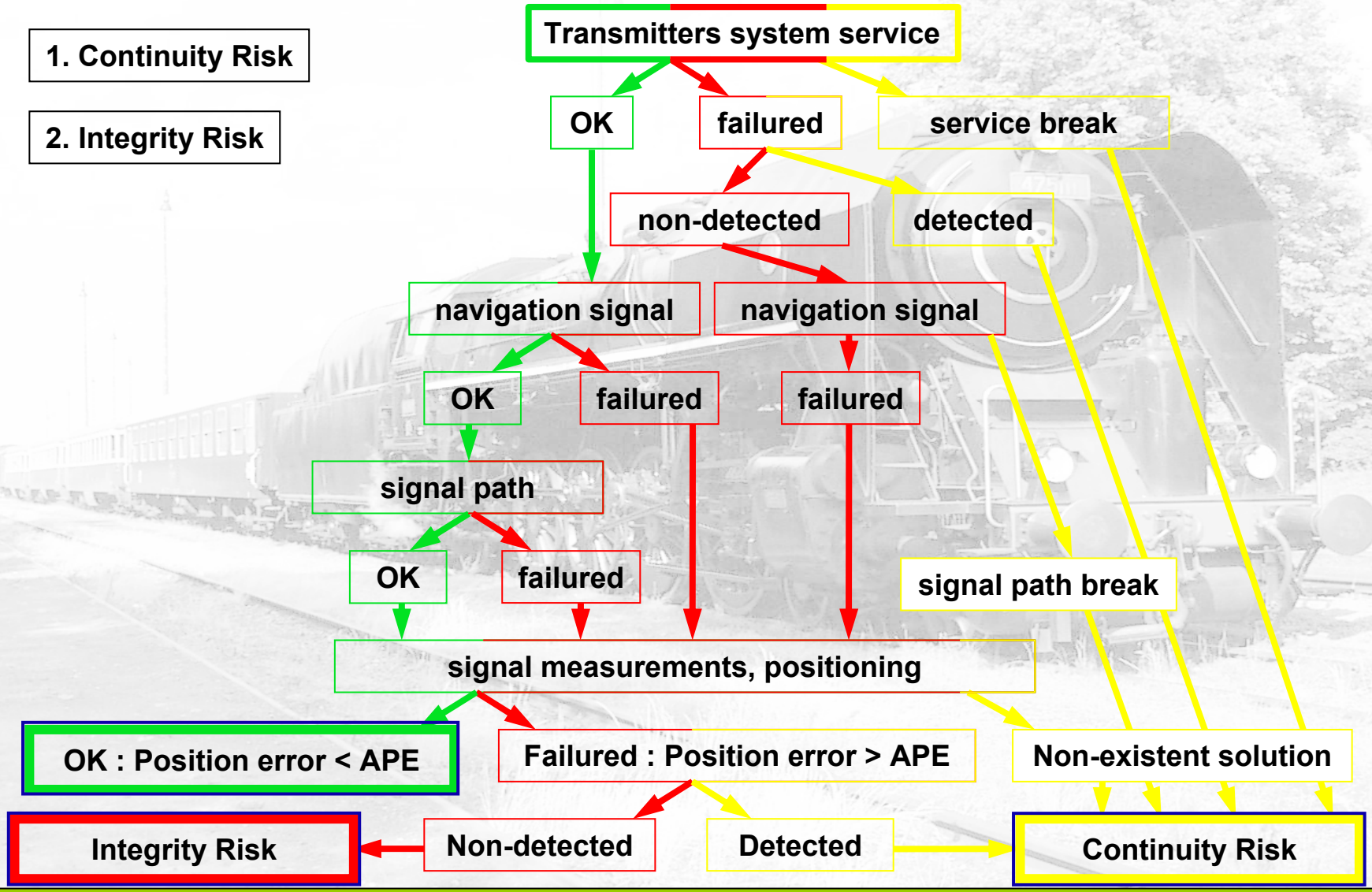
What is necessary to certification of the system?



What is necessary to certification of the system?

1. Continuity Risk

2. Integrity Risk



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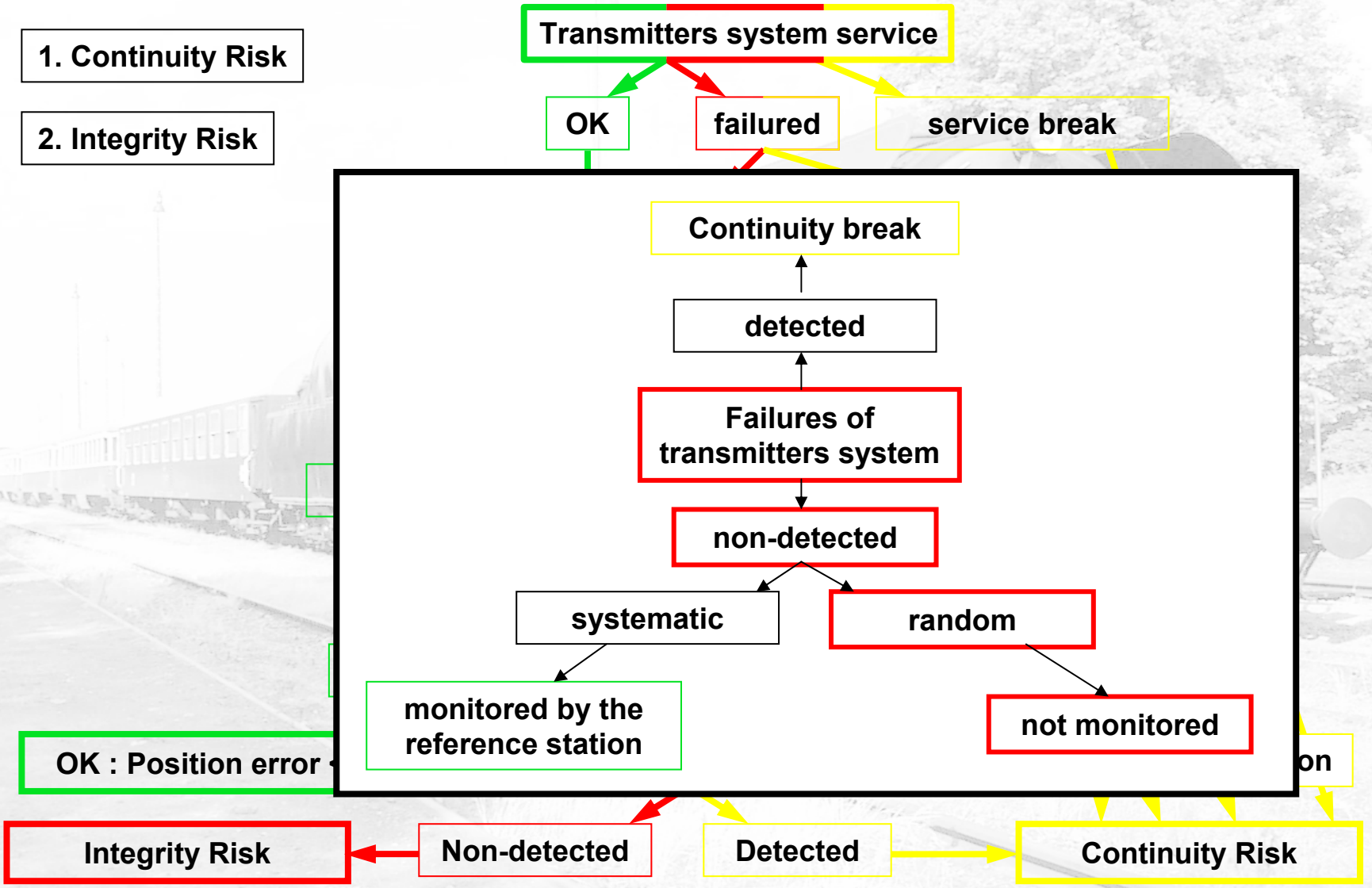
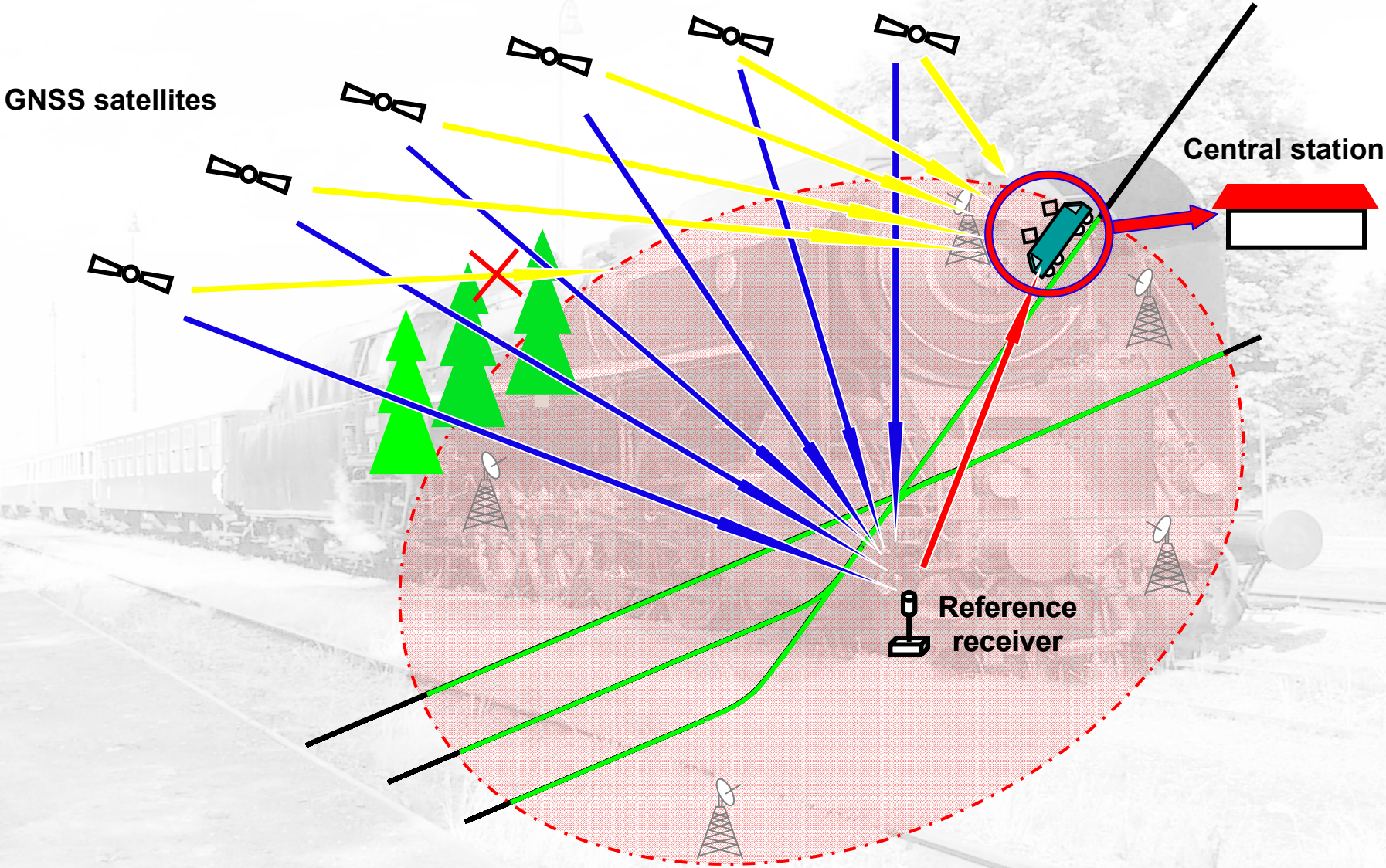


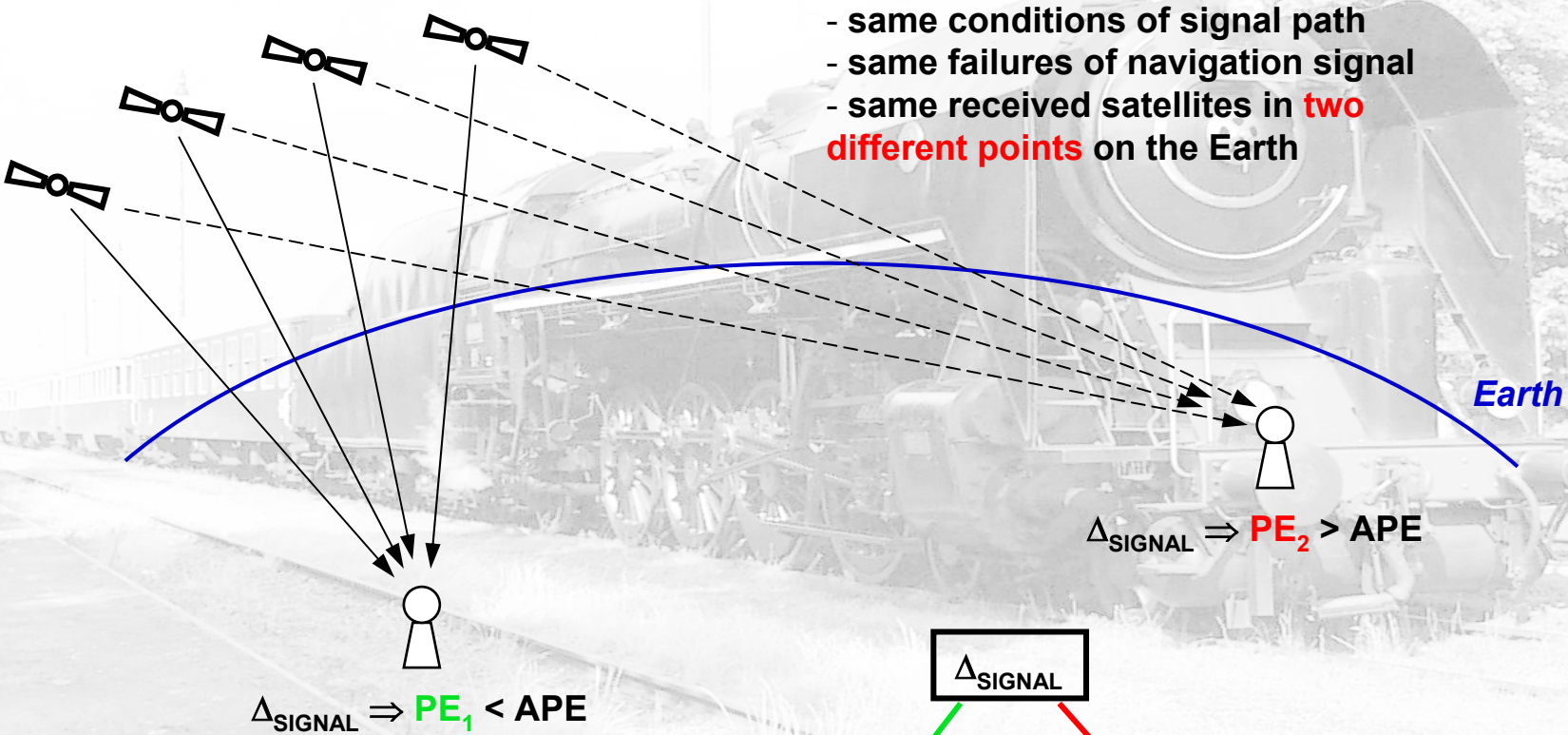
Analogic scenario of the safe positioning by the satellite system



What is necessary to certification of the satellite system?

One simply situation :

- one time
- same navigation signal
- same conditions of signal path
- same failures of navigation signal
- same received satellites in two different points on the Earth



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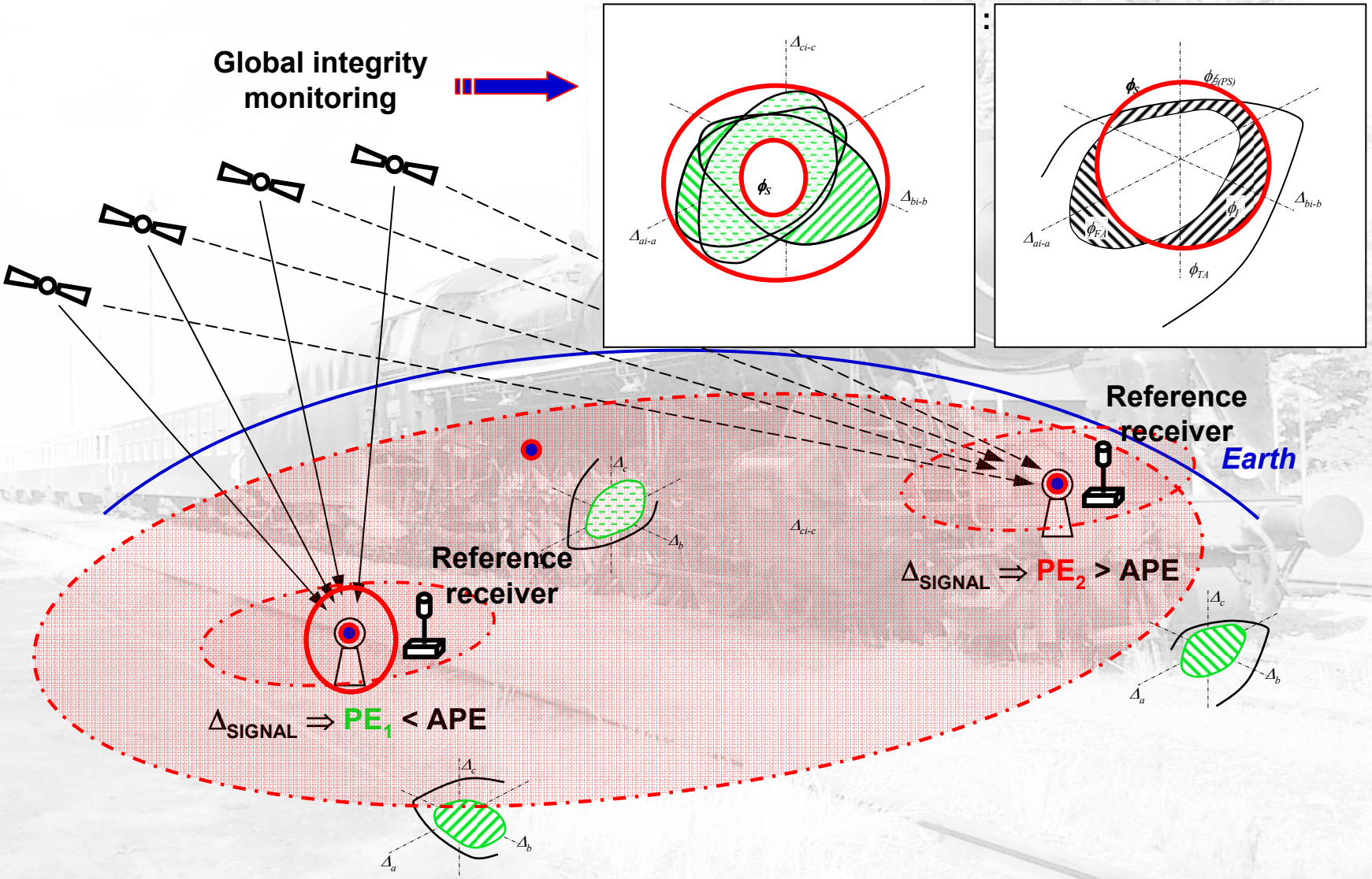

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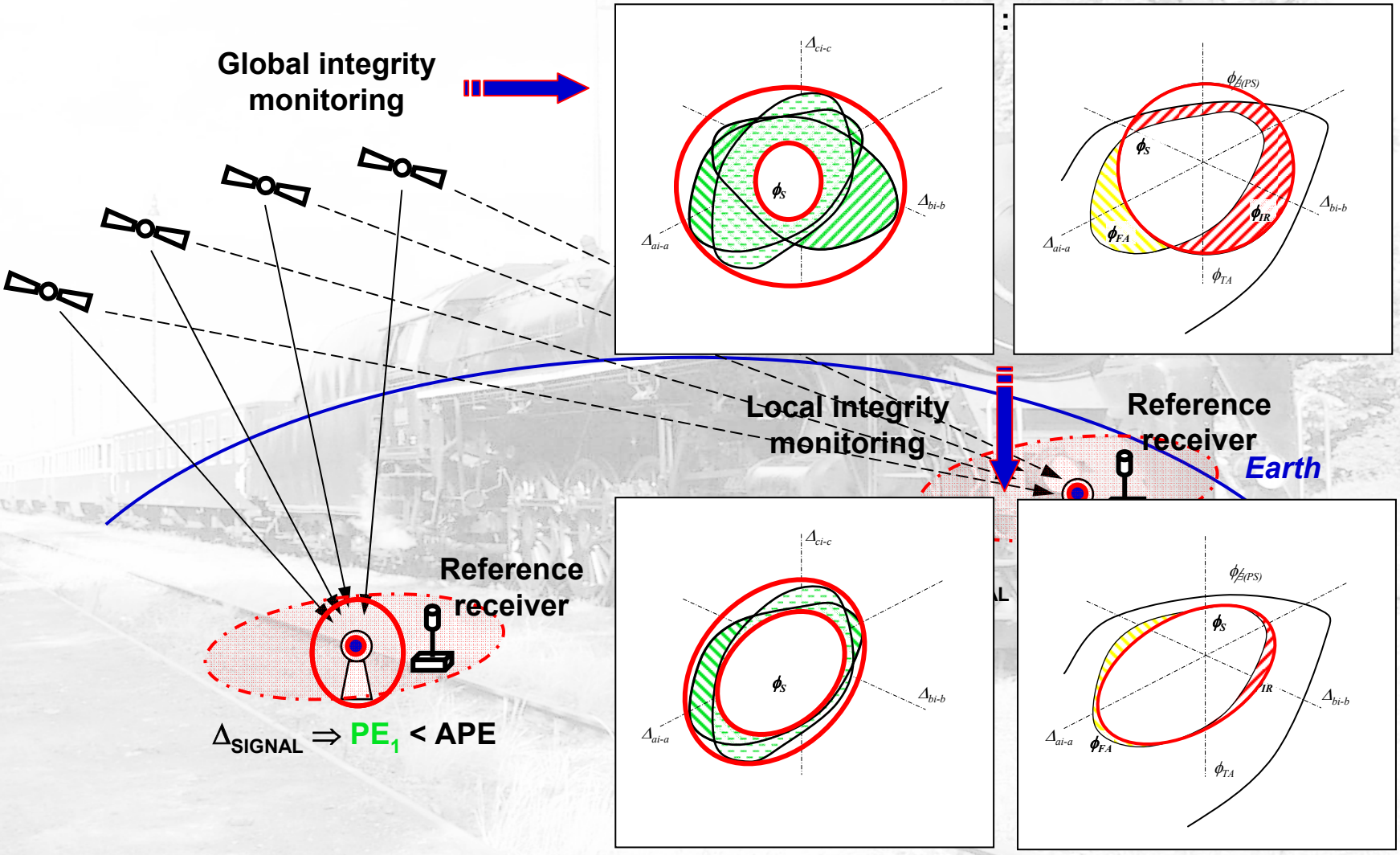

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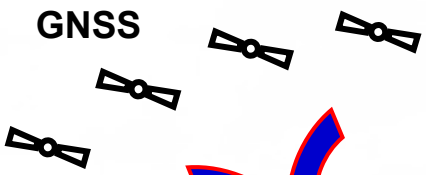


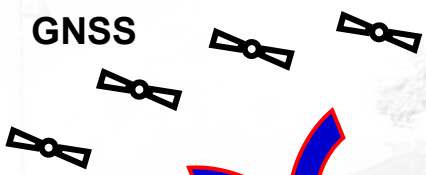
Navigation signal
Global Integrity message

GNSS Integrity message :

1. CR – risk of all breaks owing to satellite. system failures, failures on signal path, receiving and positioning failures …
2. IR – risk of nondetected dangerous failures of satellite system, all dangerous failures
positio

risks for systematic failures for positioning by
- number of satellites : 4
- radius of area of coverage : 1000 km

IR : 8.01587.10-4
CR : 3.65872.10-7
PFA : 7.15480.10-4



Navigation signal
Global Integrity message

Local Integrity message

GNSS Integrity message :

1. CR – risk of random break owing to satellite system failures
2. IR – undefinable information

Reference station Integrity message :

1. CR – risk of break owing to systematic failures of satellite system, signal path,
receivin
2. IR – r
systema
signal p

risks for systematic failures for positioning by
- number of satellites : 4
- radius of area of coverage : 500 m

IR : 1.67823.10-7
CR : 2.15784.10-8
PFA : 9.79658.10-6

Conclusions

1. **Certification of the satellite navigation system for some very critical safety related applications in global concteption and the global coverage of the integrity by the satellite system in itself is very disadvantageous.**
   Global integrity must take to account of worst conditions of signal path, minimum number of received satellites at the worst possible constelation in the whole covered area.... (a performance of basic requirements of safety applications in the railway is practically impossible).
   Certification of the GNSS/GALILEO for global using is only very small part of the certification of total positioning system used for given application.

   What it's necessary for GALILEO certification?
   Only risks related to random (non-systematic) failure, which can be global dangerous?
   And, it's possible to global cover all dangerous failure for all applications, which will require certification?

2. **At the using of the local monitorig of integrity and continuity by the reference station, it's important only information from GNSS about the continuity risk caused by random failures of the satellite system. The integrity risk for GNSS in itself at the local conception is not possible to define – because it's not possible to define the safe and dangerous failure.**

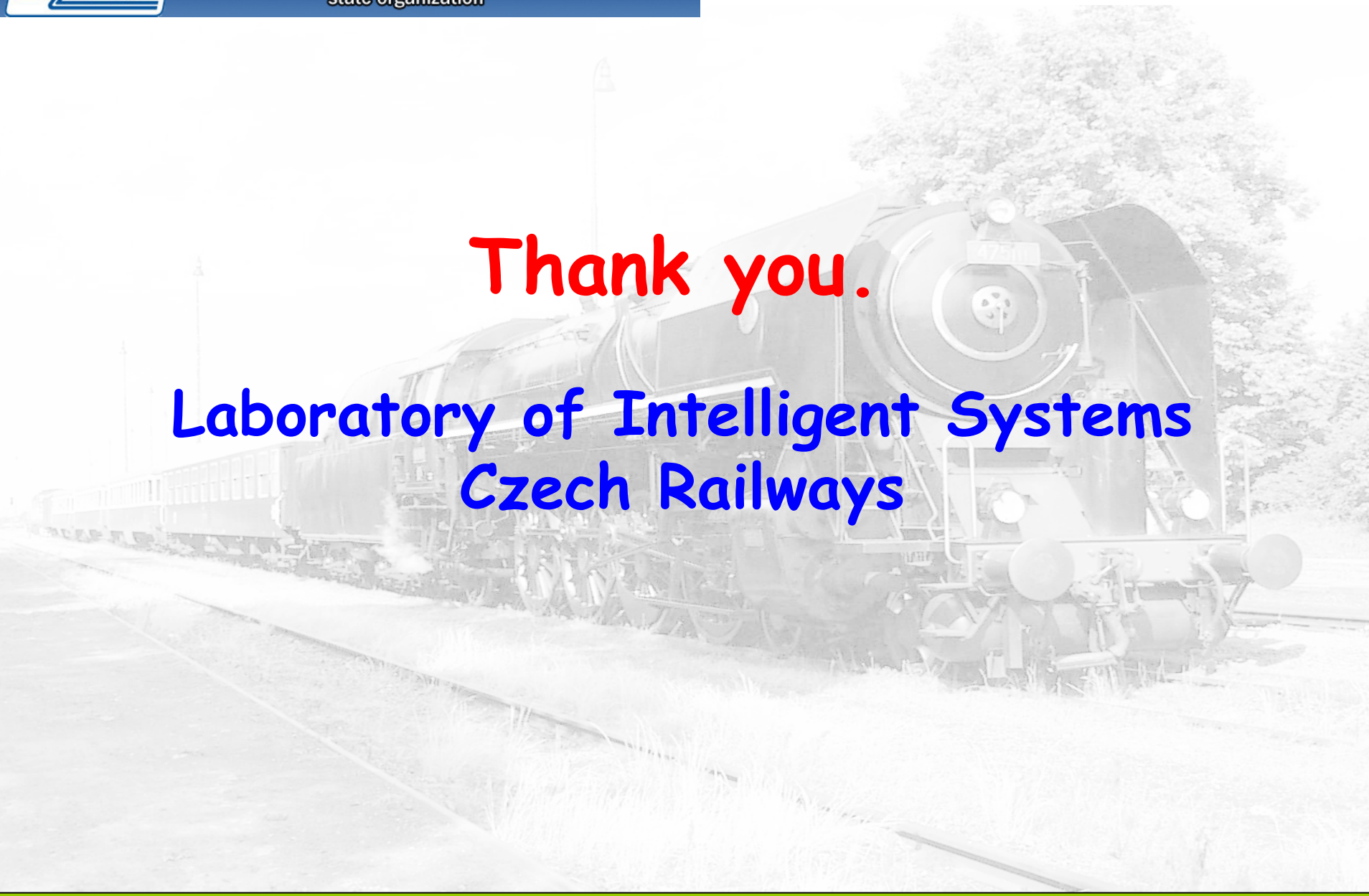
Conclusions

3. System certification must be the certification of the whole system, so system of satellites together with the signal propagation path, signal processing, measurement and finely including requiered safety related application.

4. Using of filters for measured data (usually based on the Kalman filterig method) increases generally the accuracy of position solution, but, at the same time it can be also a source of errors and it would have to also monitored.

Acknowledgement

All presented results were supported by the Czech Science Foundation under contract No. 102/06/0052 and Czech Ministry of Transport under contract No. CG 743/037/520.



Thank you.

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