ICAO CAPACITY & EFFICIENCY

ASECNA Workshop on ADS-B
(Dakar, Senegal, 22 to 23 July 2014)

SSR Mode S Coordination Issues

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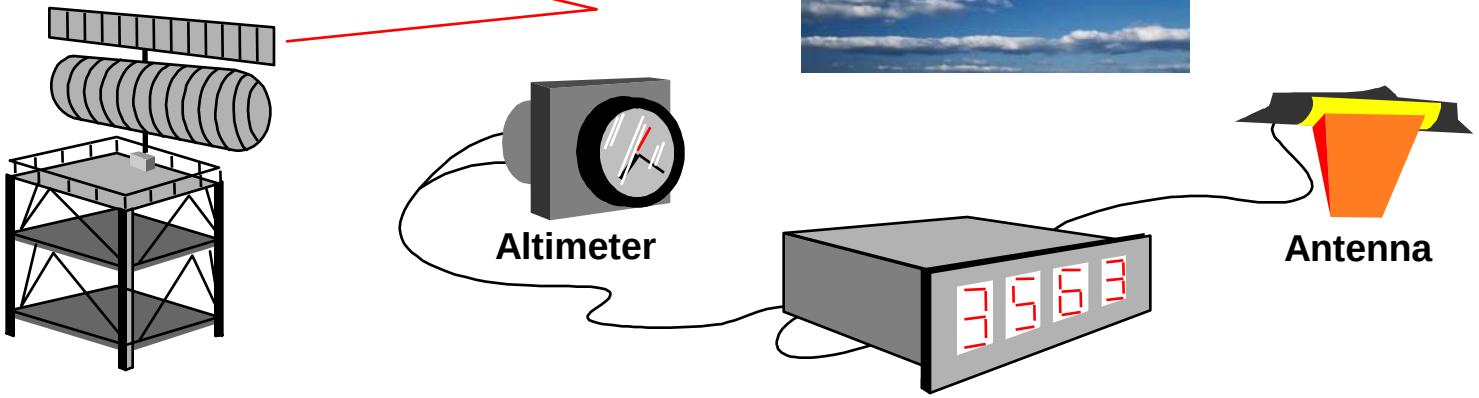
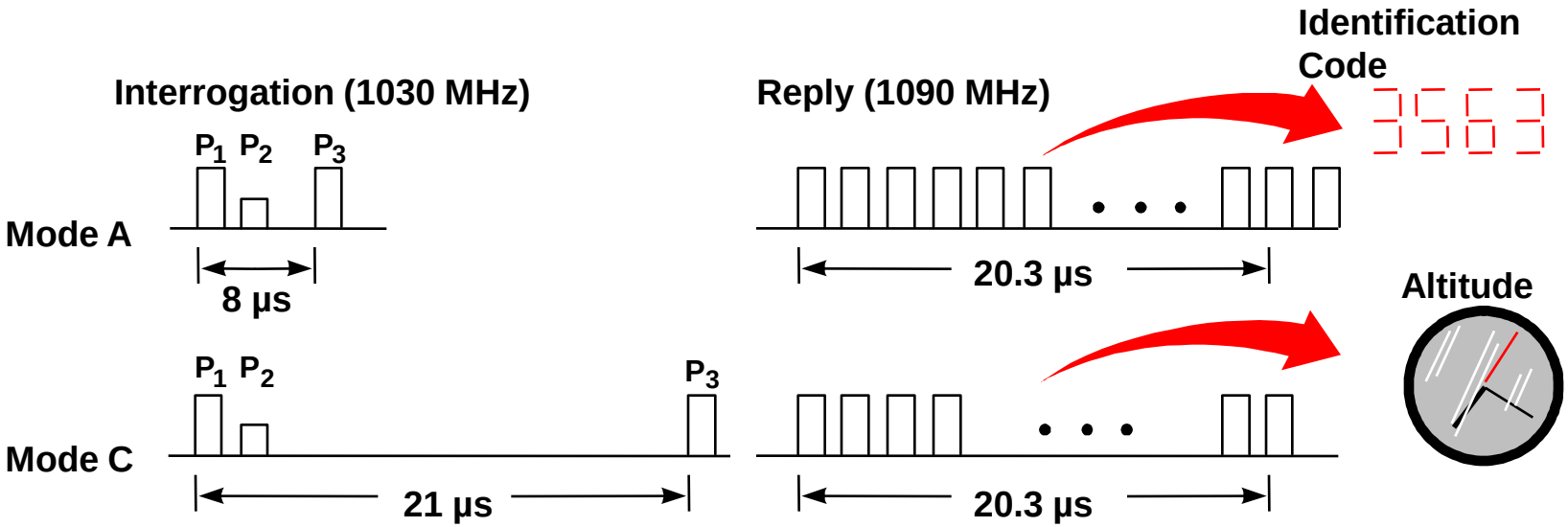
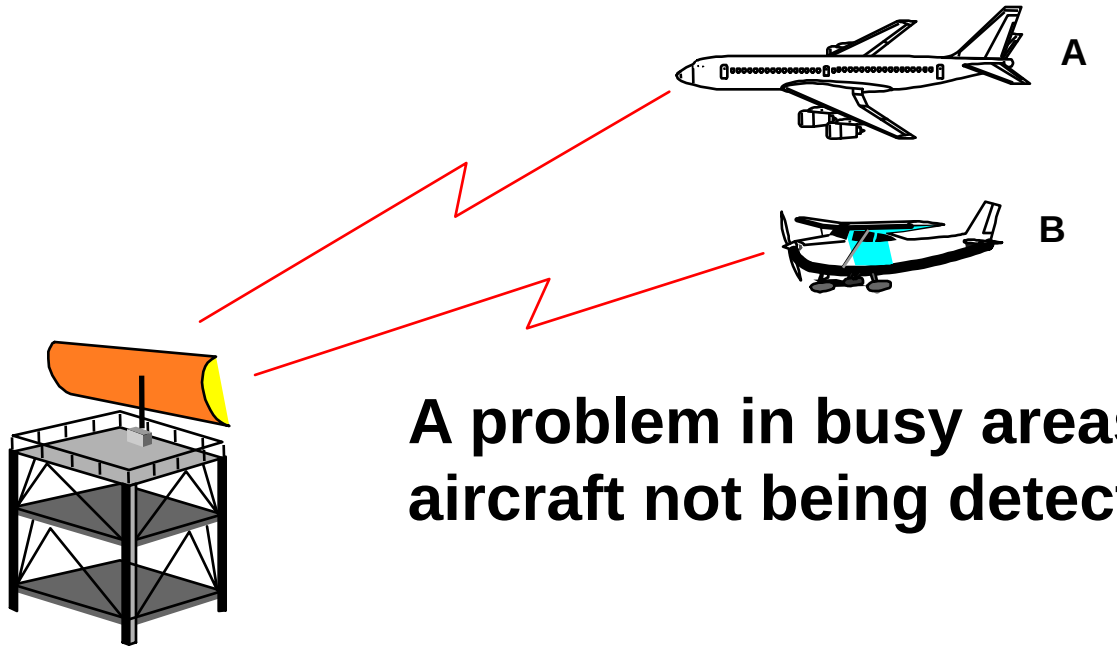
Secondary Surveillance Radar (SSR) Modes A and C





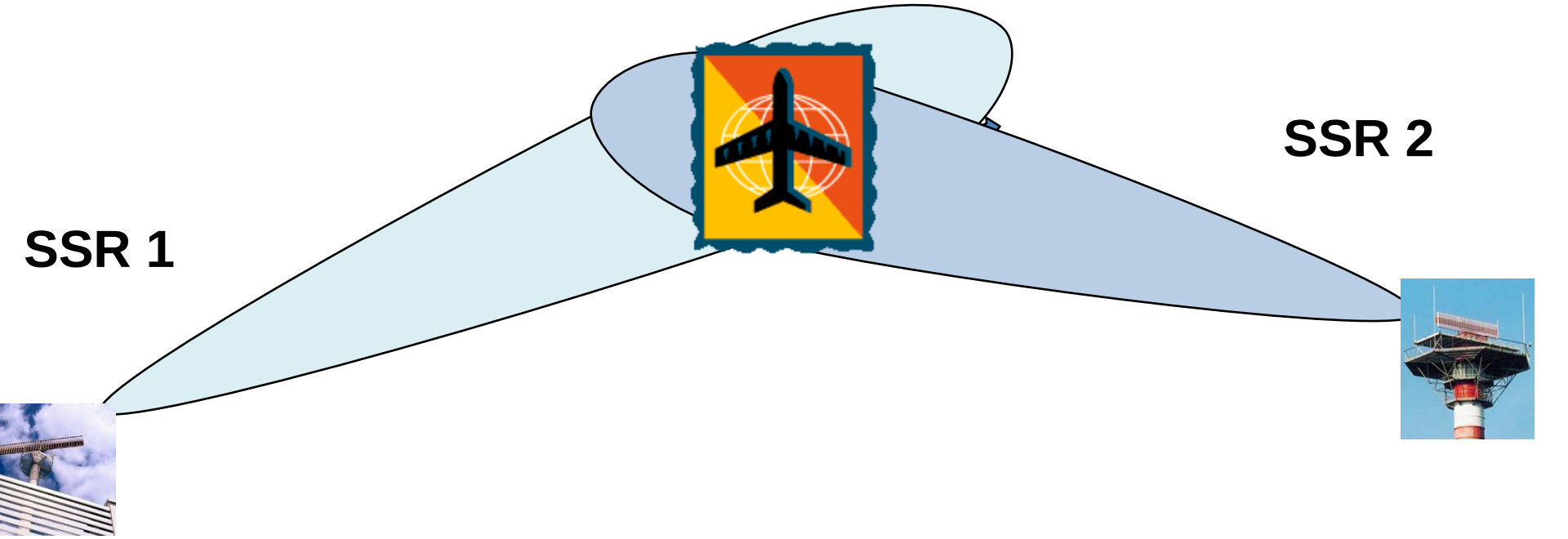
Synchronous Garbling of Transponder Replies



A problem in busy areas resulting in some aircraft not being detected

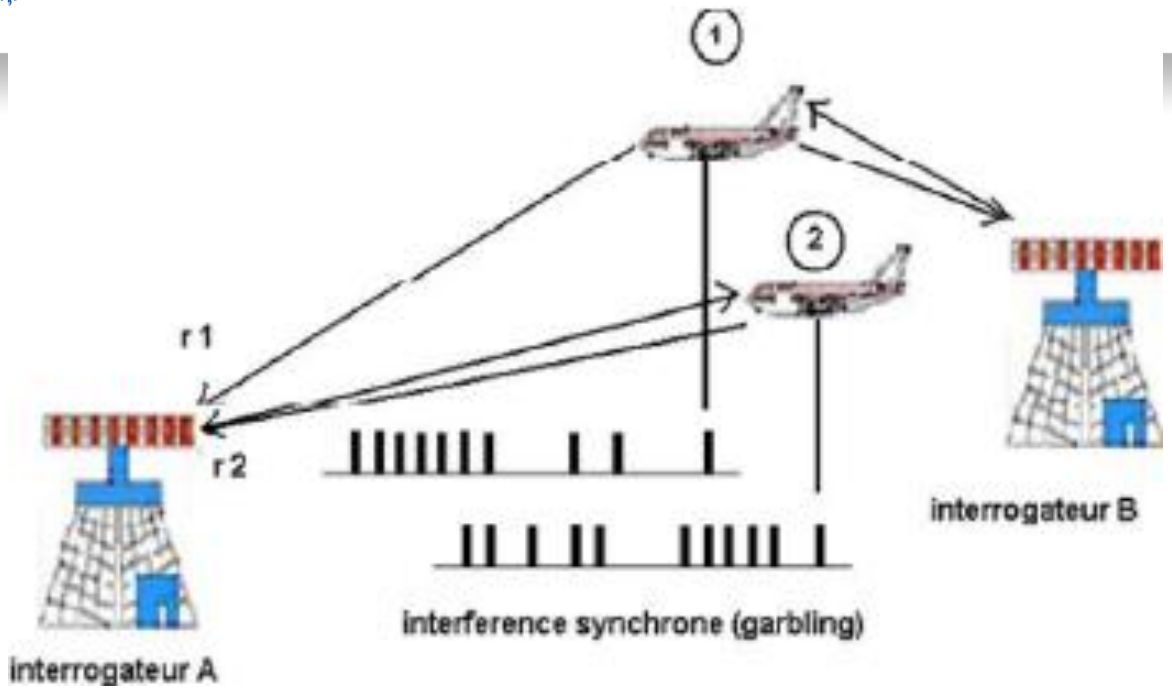
- **Replies A & B Garble When Aircraft Are < 2 Miles Apart in Slant Range**

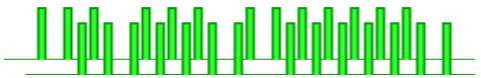
Garbling of interrogations



Adjacent SSRs have the same pulse repetition frequencies (PRFs) – if **pulses collide or are too close, the aircraft won't be detected**

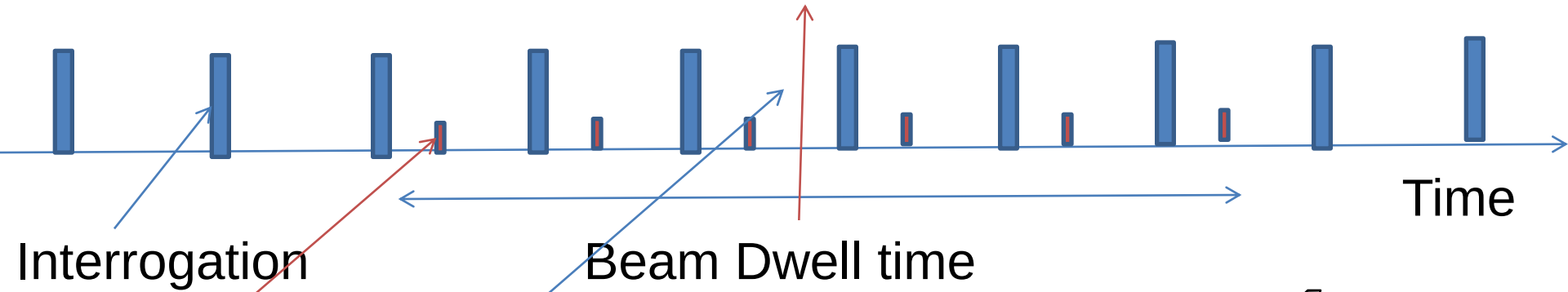
Asynchronous (FRUIT)

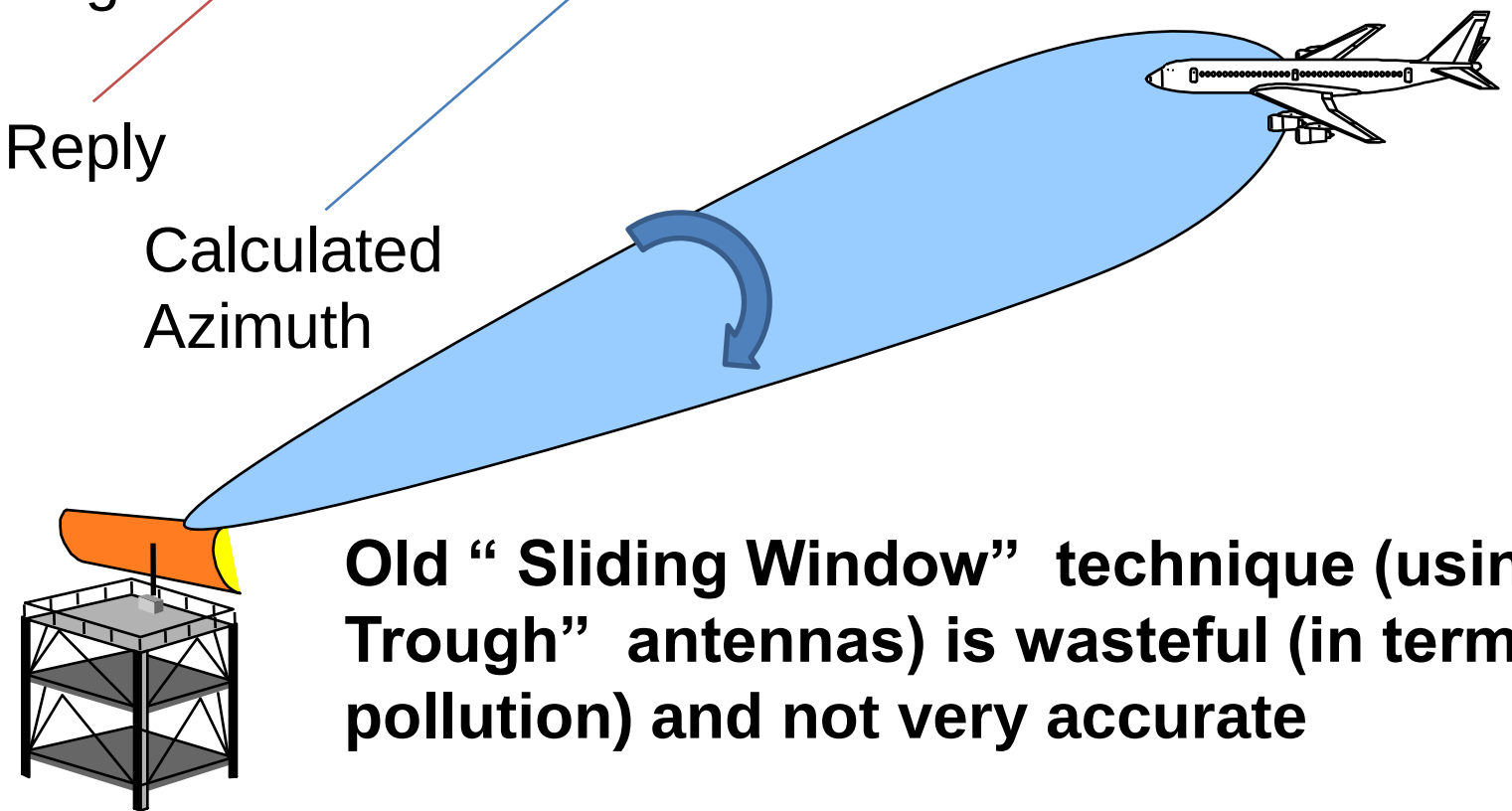




- Station **B** Transmits to A/C **A** and receives a correct synchronous response; although this response is dedicated to B Interrogator **A** also received (**R1**)

- Interrogator A Transmits to A/C **B** and receives a correct synchronous response **R2** but this response is garbled by unsyncronised response **R1**

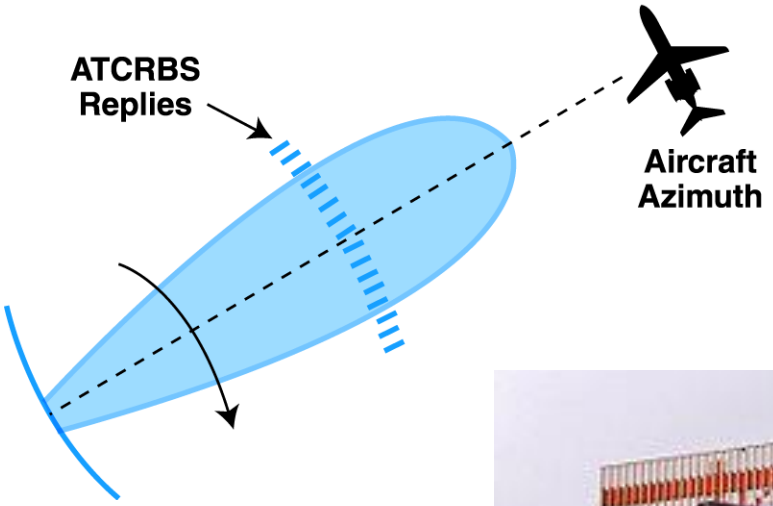




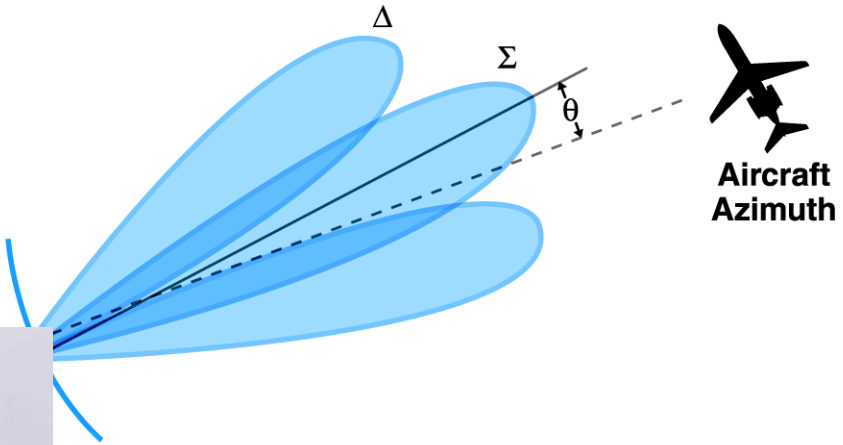
Old " Sliding Window" technique (using " Hog Trough" antennas) is wasteful (in terms of RF pollution) and not very accurate

Monopulse Direction Finding (with Large Vertical Aperture (LVA) antenna)

ATCRBS SENSORS USE SLIDING WINDOW DETECTOR



MODE S SENSORS USE MONOPULSE TECHNIQUE

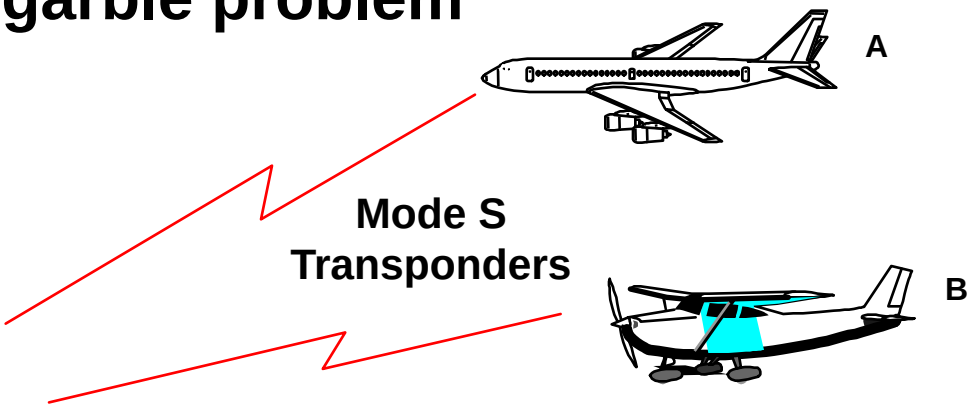


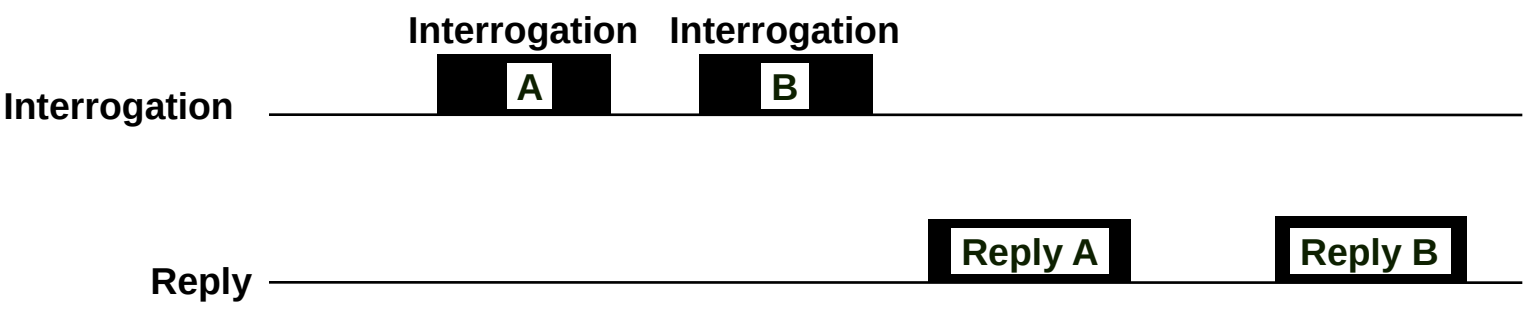
CS:

- **SUSCEPTIBLE TO AZIMUTH SPLITS**
- **HIGH PULSE REPETITION FREQUENCY**

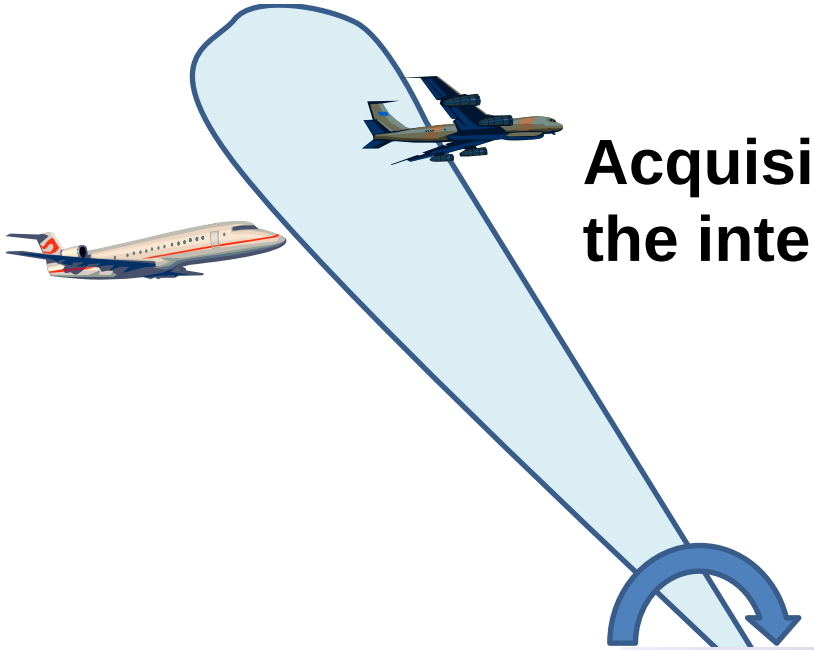
- USES ANTENNA SUM & DIFFERENCE BEAMS TO ESTIMATE AZIMUTH FOR EACH REPLY
- ALLOWS LOWER PULSE REPETITION FREQUENCY

Mode S and monopulse technique an solves the synchronous garble problem





But the interrogator needs to know each aircraft 24 bit address before it can selectively interrogate them



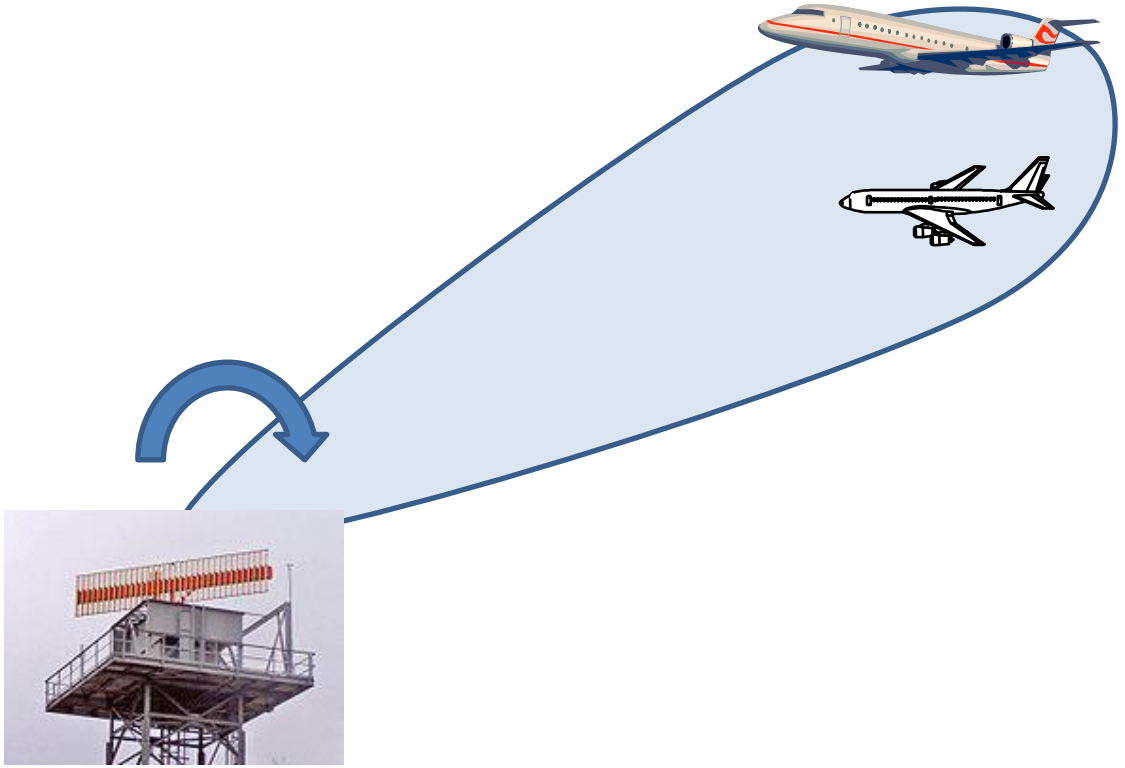
Acquisition of all aircraft in coverage by the interrogator

1: The interrogator sends out an All-Call signal

2. Each A/C in coverage replies giving its 24 bit address

3. Having acquired all A/c in coverage, the interrogator selectively interrogates every A/C (roll–call)

So the same synchronous garble can happen with Mode S as well for A/Cs in close slant range



However, Mode S can do adoptive interrogations. The Stochastic All-call interrogation asks for replies to be sent with a probability of less than 1. Chances are the two A/Cs come up with different probabilities so both don't reply to each interrogation. So both are acquired.

Mode S Acquisition and Lock out

Once an aircraft is “ **acquired**” by the ground radar, ideally it should not reply to subsequent **All-call** interrogations.

That is why the interrogator can “**lock out**” an already detected aircraft from replying to further **All-call** interrogations.

However, the aircraft should be able to reply to **All-call** interrogations **from other/adjacent radars**.

This is why each interrogator can have its own “ **I**nterrogator **C**ode (**IC**)”.

Benefits

* immune to garbling/Less RF pollution

* selective (addressed interrogations) based on 24-bit aircraft addresses

* relief from Mode A code shortage (when Aircraft Identification is used)

* Additional information (e.g. identity and pressure altitude in 25 ft increments)

* uses error detection so data is accurate

* Offers an A-G data link medium (up to 112 bits in every signal)

Advantages of SSR Mode S (over Mode A/C)

Better overall performance and in high density areas, improves the safety of air navigation.

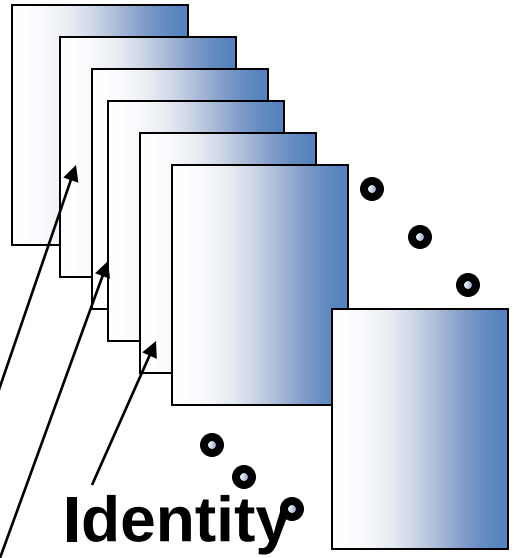
However, Mode S is rather complicated (mainly for the technical personnel). So its use in not-so-high density areas should be carefully considered.

Many parameters need to be properly set/adjusted and often in coordination with adjacent radars.

* **Pulse repetition frequency (PRF)**
* **Mode interlace pattern (A/C, All-Call A/C/S, All-Call Mode S only, Roll-calls)**
* **Interrogator Code (IC)**
* **Use of lockout (coverage and protocol)**
* **Use of datalink capability**
* **Types of transponders in the airspace**

The Mode S Transponder has 256 registers

Registers (00 to FF $_{HEX}$) contain A/C information



Track and Turn Report

Heading and Speed Report

Mode S transponder

Registers enable downlinking (and broadcasting) of A/C data

Transponder Registers Data

Operational requirements may dictate that some of the registers in the Mode S transponder be fed with aircraft data and their contents be downlinked to ground (as part of replies).

Regional mandates are needed to force the appropriate aircraft equipage and configuration. For examples:

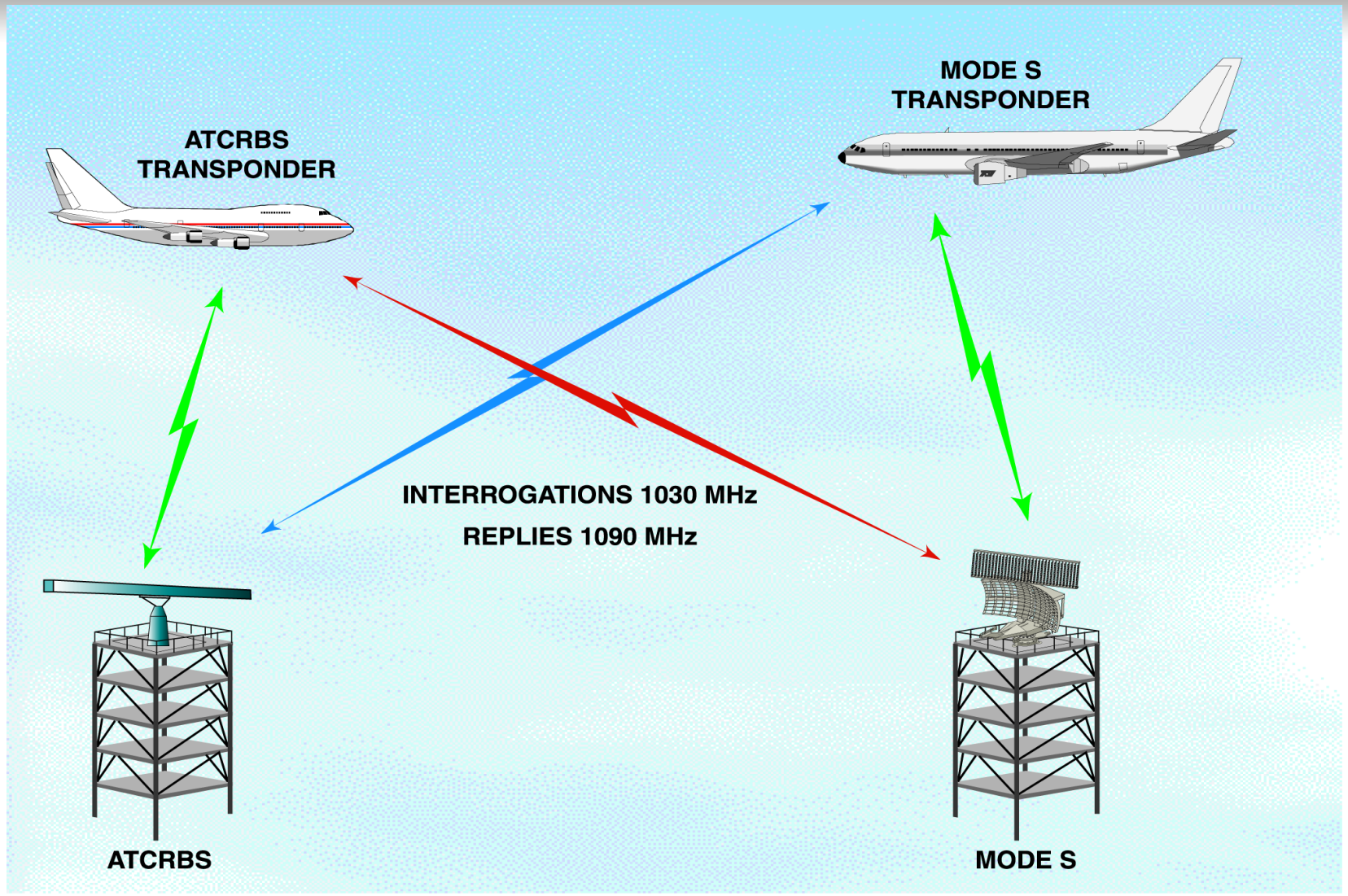
1. European Elementary Surveillance (ELS) Mandate:

- Aircraft identification

2. European Enhanced Surveillance (EHS) Mandate:

- Selected Altitude, Track Angle Rate, Roll Angle, True Track Angle, Ground Speed, Magnetic Heading, Air S peed and Vertical Rate

Compatibility Between Mode A/C and Mode S



Lockout and Interrogator Codes

- Once the transponder is on discrete address roll call, further response to All-Calls would cause interference
- Interrogator commands transponders on its roll call to not reply to its All-Calls (All-Call Lockout)
  - Lockout command contained in discrete interrogation
  - Times out in 18 seconds
- All-Call lockout is interrogator specific
  - Lockout command specifies 4-bit Interrogator Identifier (II) code
  - Transponder replies if not locked out to that interrogator code

Coordination requirements (*Annex 10 Vol. IV*)

Note.— In order to permit the efficient operation of ground equipment designed to eliminate interference from unwanted aircraft transponder replies to adjacent interrogators (defruiting equipment), States may need to develop coordinated plans for the assignment of pulse recurrence frequencies (PRF) to SSR interrogators.

2.1.2.1.2 The assignment of interrogator identifier (II) codes, where necessary in areas of overlapping coverage, across international boundaries of flight information regions, shall be the subject of regional air navigation agreements.

2.1.2.1.3 The assignment of surveillance identifier (SI) codes, where necessary in areas of overlapping coverage, shall be the subject of regional air navigation agreements.

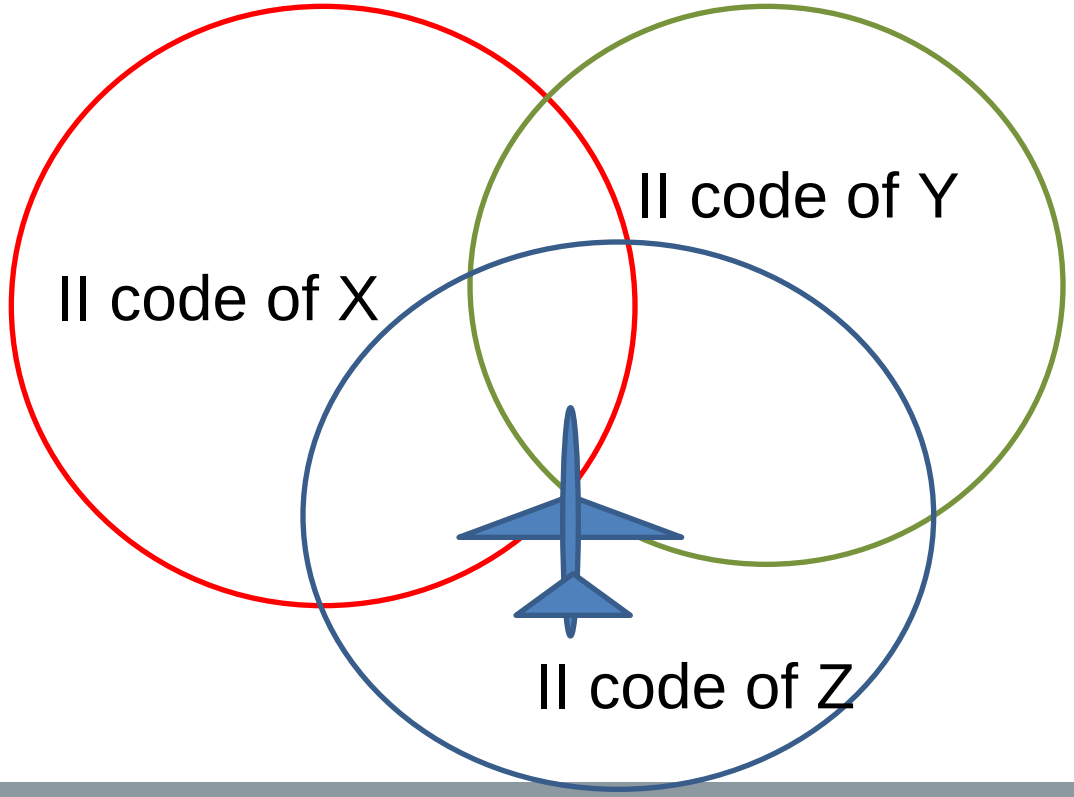
Note.— The SI lockout facility cannot be used unless all Mode S transponders within coverage range are equipped for this purpose

Interrogator Identifier Codes (IC II) & Lockout

16 Interrogator Identifier (II) codes from 0 to 15

An issue when:

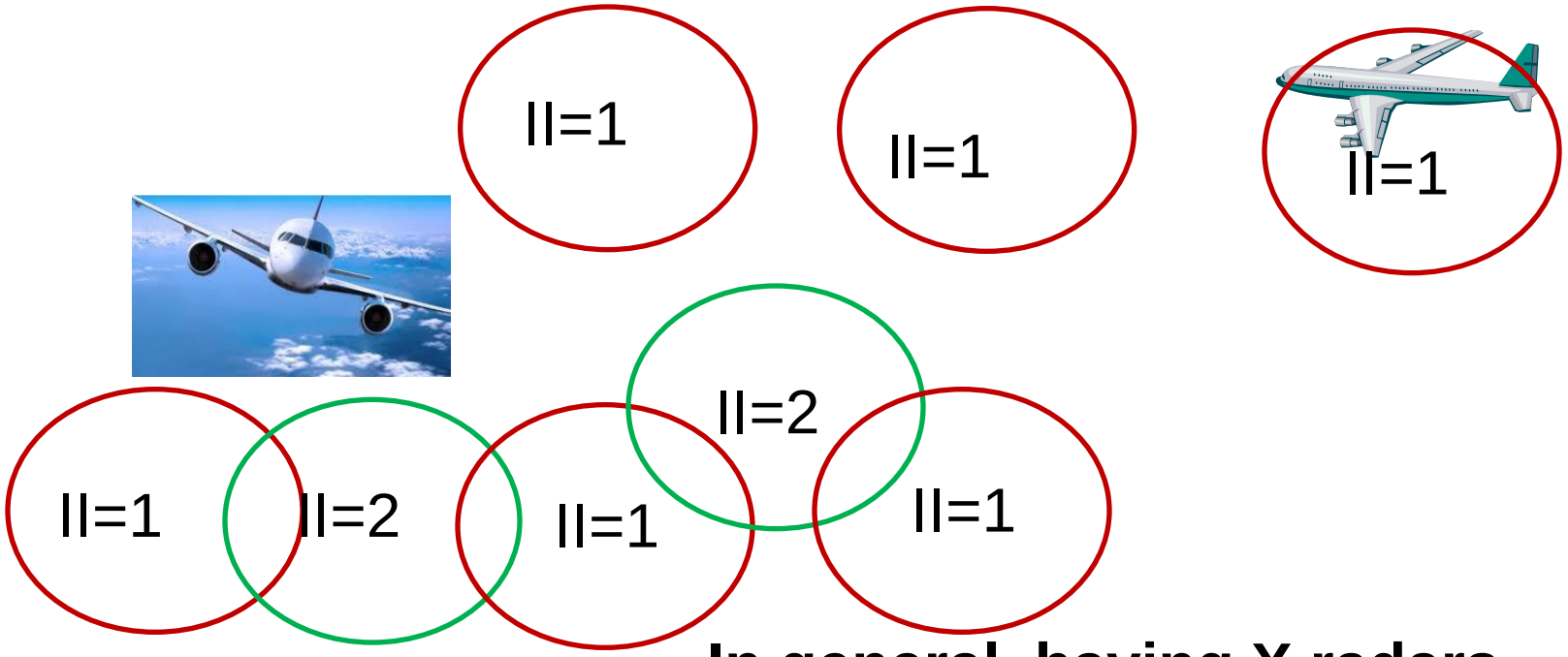
- **Adjacent radars have overlapping coverage; and**
- **Lockout is to be used by any of the radars**

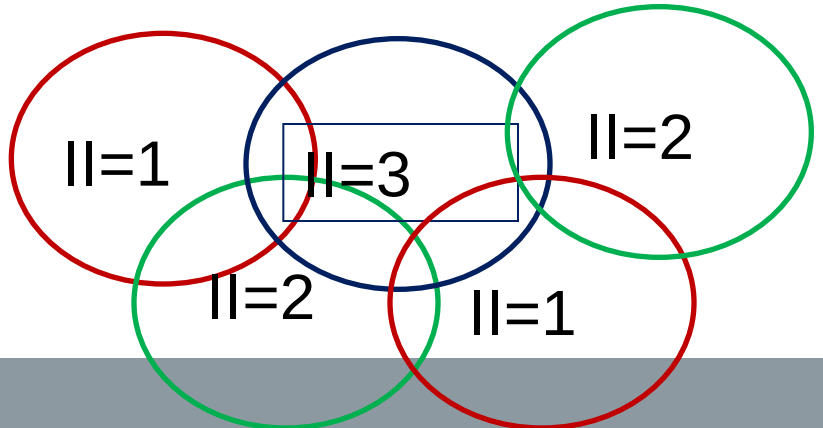


AC locked out by Z can still be acquired by X and Y once it reaches their coverage

Examples of II Assignment

16 Interrogator Identifier (II) codes from 0 to 15





In general, having X radars doesn't equate to X ICs being needed!
Neither it means a computer tool is needed!

SI Codes

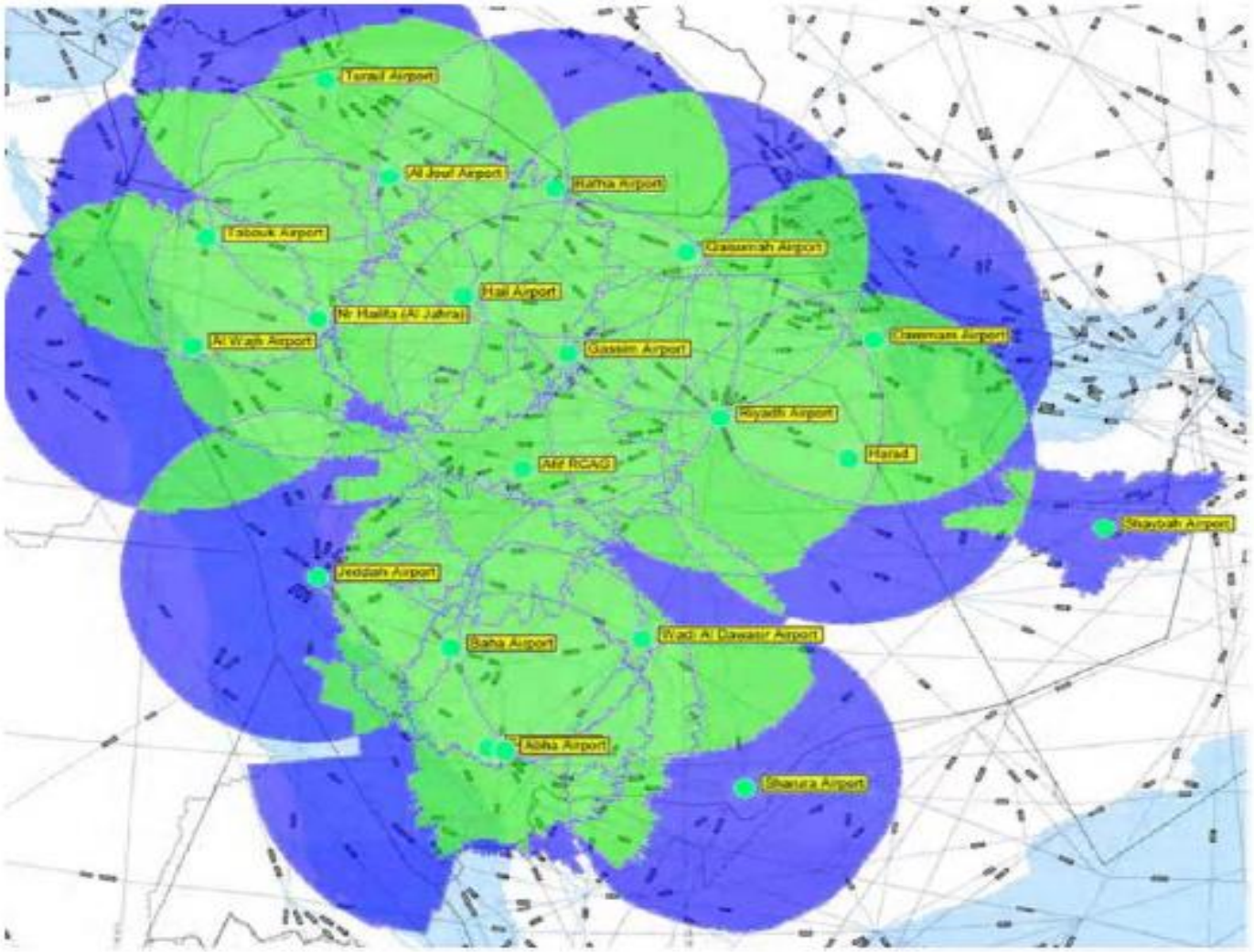
- **Interrogator codes are needed for independent operation of adjacent Mode S sensors**
  - **Current II codes not adequate for both civil and military needs**
  - **6-bit Surveillance Identifier (SI) code will provide 63 additional interrogator codes**
- **SI codes now required by Mode S standards and European Mode S mandates**
  - Will not be used until all aircraft in a region of airspace are equipped !
  - Regional coordination a must!

Computerizing II code Assignment

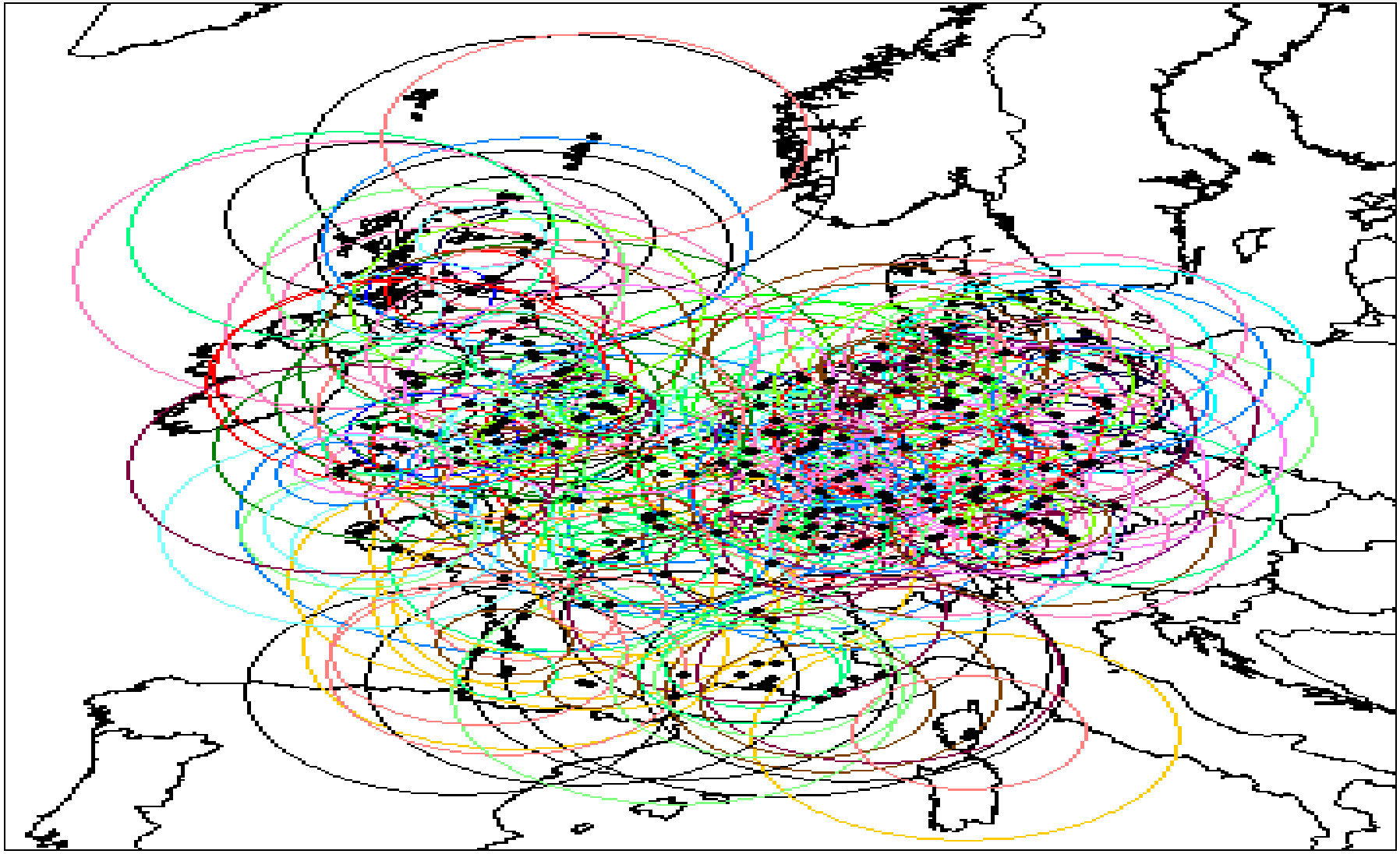
* A computer tool would however be useful for assigning interrogator codes (interrogator identifier (II) and/or surveillance identifier (SI)) in areas where there are many Mode S radars with overlapping coverage (like the areas shown in the next two slides)

* In such areas, a single body would be better suited to assign the codes (and to look after other Mode S issues) in coordination with individual States

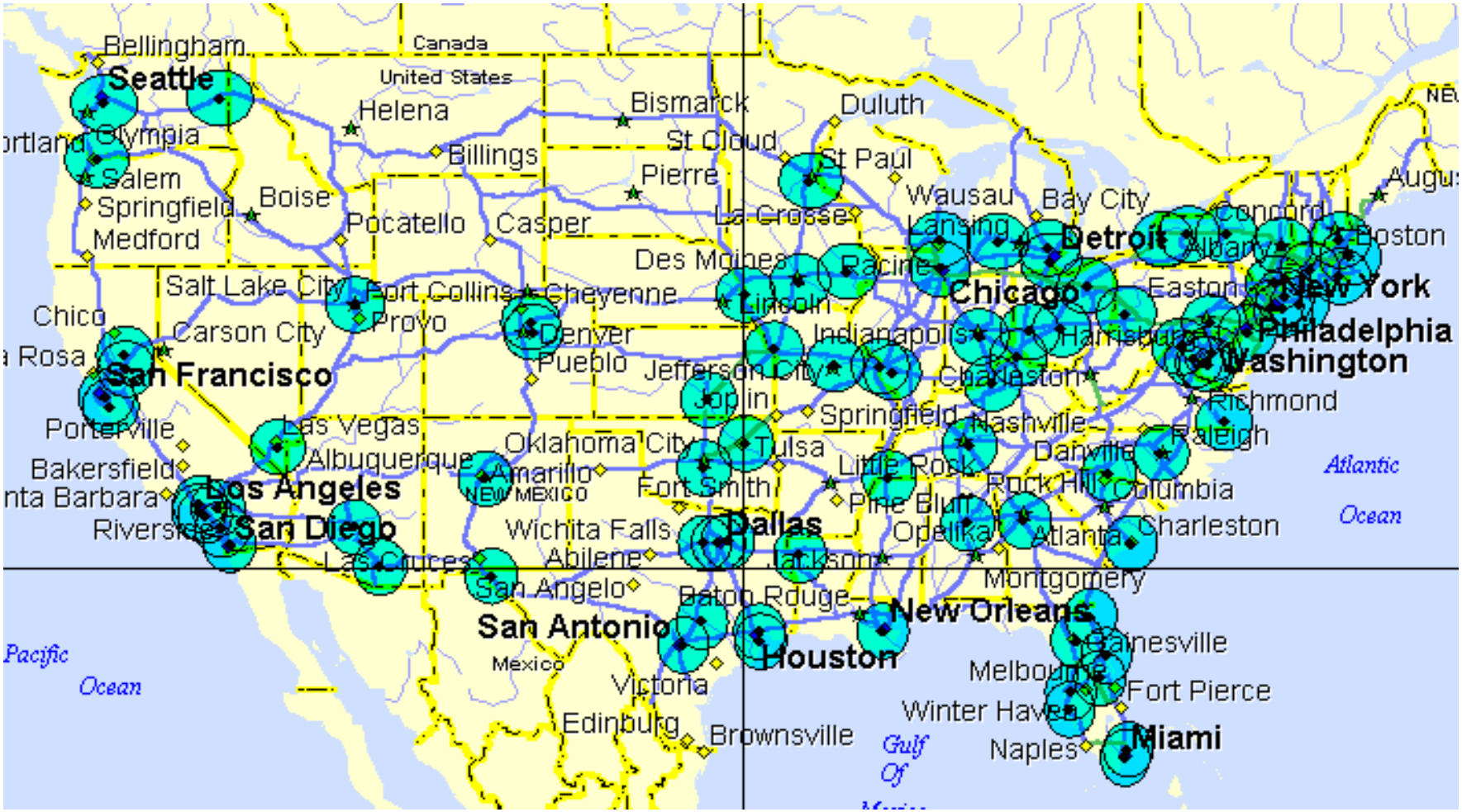
A Real Example: Mode S Radars In Saudi Arabia



European Mode S Radars



Mode S Radar Coverage in the U.S.



Civil/Military Coordination

- Awareness of military radars (land-based, ship borne, etc)
- It may not be possible to get details of those radars but assignment of IC should be coordinated with appropriate military authorities

Summary

* Nowadays, a modern SSR comes with Mode S

* Mode S has many features, not all are needed everywhere

* According to Annex 10, decisions on PRF, lockout coverage and use of interrogator codes must be based on regional agreements

* Regional Offices may be asked by some States to assist with assigning interrogator codes. They therefore need to know the locations of all such radars in the given geographic area, any existing IC used and the documented use of lockout operations if any. Then, if only a handful of radars exit, the assignment better be done manually. If however many sites are involved, a computer tool (such as the one under development by ICAO) could be helpful.

Appendix Some Relevant Annex 10 Provision

2.1.2.1.1 **Recommendation.—** ***Administrations should coordinate with appropriate national and international authorities those implementation aspects of the SSR system which will permit its optimum use.***

Note.— In order to permit the efficient operation of ground equipment designed to eliminate interference from unwanted aircraft transponder replies to adjacent interrogators (defruiting equipment), States may need to develop coordinated plans for the assignment of pulse recurrence frequencies (PRF) to SSR interrogators.

Annex 10 Provisions (con'td)

2.1.2.1.2 The assignment of interrogator identifier (II) codes, where necessary in areas of overlapping coverage, across international boundaries of flight information regions, shall be the subject of regional air navigation agreements.

2.1.2.1.3 The assignment of surveillance identifier (SI) codes, where necessary in areas of overlapping coverage, shall be the subject of regional air navigation agreements.

Note.— The SI lockout facility cannot be used unless all Mode S transponders within coverage range are equipped for this purpose.

2.1.3.3.1 Requirements for mandatory carriage of SSR Mode S transponders shall be on the basis of regional air navigation agreements which shall specify the airspace and the airborne implementation timescales.

Annex 10 Provisions (End)

3.1.2.11.6 ***Lockout coordination. A Mode S interrogator shall not be operated using all-call lockout until coordination*** **has been achieved with all other operating Mode S interrogators having any overlapping coverage volume in order to ensure that no interrogator can be denied the acquisition of Mode S-equipped aircraft.**

Note.— This coordination may be via ground network or by the allocation of interrogator identifier (II) codes and will involve regional agreements where coverage overlaps international boundaries.

Other documents:

Manual on the SSR Systems **(Doc 9684)**
Aeronautical Surveillance Manual (Doc 9924) **– on ICAO-Net**

Thank you for your Kind attention !

Any Question????

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