CNES PROCESSING STRATEGY
AT THE SERVICE D'ORBITOGRAPHIE DORIS
(SOD)

SOD PROCESSING STRATEGY

- **The Service d'Orbitographie DORIS**
  - **is not an institutional entity but part of the orbit determination department**
  - **is now working within the Altimetry and Orbit Determination ground system SSALTO**
- **Processing is operational**
  - **key function is to produce rapid and precise orbits for altimetry missions (TOPEX, Jason, ENVISAT)**
  - **processes are designed to operate automatically in any condition such as maneuvers and incidents**
  - **many steps have been added to increase robustness based on previous experience even though they would not be required on a day to day basis**

Overview

- Processing is a combination of elementary functions
- Key functions are
  - **GP** "geometrical" preprocessing which edits data based on elevation angle, length and symmetry of pass, ...
  - **DP** "dynamical" preprocessing which edits data based on residuals with respect to a "navigation" solution with slant range and timing biases adjusted
  - **OD** orbit determination which computes orbits with various combinations of adjusted parameters
  - **TD** time determination which estimates the relation between on-board time and TAI in the form of a polynomial
  - **AI** auto initialization which estimates initial conditions directly from the DORIS data without any external information
  - **FD** on-board frequency determination which estimates the on-board USO frequency offset in the form of a polynomial
- Processing chain are mostly a succession of these functions

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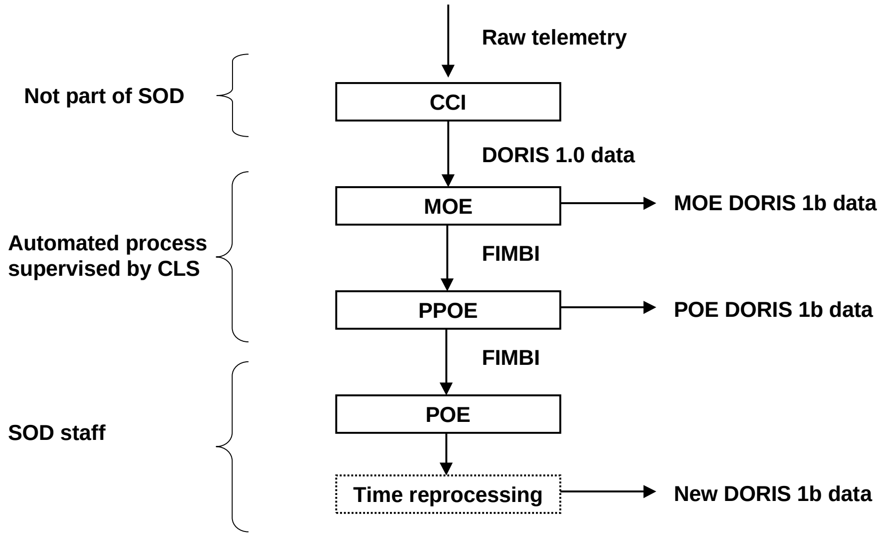
Overview (2)

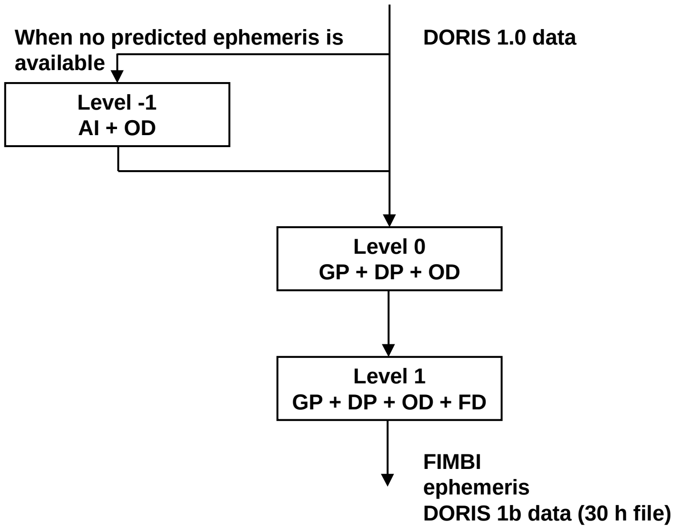


Raw telemetry
Not part of SOD
CCI
DORIS 1.0 data
Automated process supervised by CLS
MOE
MOE DORIS 1b data
FIMBI
PPOE
POE DORIS 1b data
FIMBI
SOD staff
POE
Time reprocessing
New DORIS 1b data

CCI

- Decommutates telemetry to extract DORIS data
- Removes data flagged as bad by the receiver
- Compute the timetags of DORIS data
  - using a predicted ephemeris
  - model the time evolution as a polynomial
    - linear per day or
    - quadratic over 4 days
- Generates the DORIS 1.0 data products which contain nearly everything
  - timetags are provided but not the timing polynomial
  - timetags are rounded to the nearest microsecond

MOE



When no predicted ephemeris is available

DORIS 1.0 data

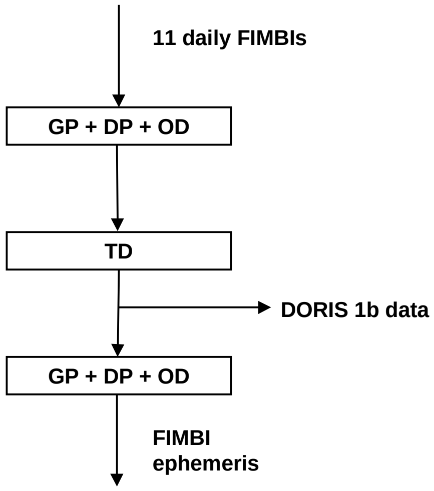
Level -1
AI + OD

Level 0
GP + DP + OD

Level 1
GP + DP + OD + FD

FIMBI
ephemeris
DORIS 1b data (30 h file)

PPOE



POE and new data

- **The POE is the result of an expert improvement of the PPOE**
  - **based on detailed analysis of residuals and empirical corrections**
  - **includes validation and intercomparison steps**
  - **revision of the delivery data following the POE step are exceptional**

- **An additional step to produce the new data**
  - **P. Willis legitimate request for coherent on-board time and frequency lead to the development of a modified datation function**
  - **this new function will replace the old one in the future**
    - it interacts strongly with the whole processing chain (suppression of the frequency modeling step)
    - it can only be integrated after the commisioning phases for the new satellites
  - **this step requires manual intervention**

DORIS 1b data

- **Key concepts**
  - **provide data in a form as independent from the receiver technology as possible**
  - **replace dual**
    ionosphere c
  - **compatible w**
- **Key equation**
- **Key variations**
  - **origin of the**
  - **nature of the**
  - **value of the c**

Current CDDIS data (1.0):
- on-board frequency from frequency determination (polynomial)
- beacon frequency from pass solution
- t1, t2 times are TAI
- deltaT = actual TAI count interval (truncated on file)

Proposed revised format (2.0?):
- nominal frequencies
- t1, t2 times are on-board time
- deltaT = exact rounded TAI count interval

Modified revised format (2.1?):
- on-board frequency from timing polynomial
- nominal beacon frequency
- t1, t2 times are TAI (to check)
- deltaT = exact rounded TAI count interval

Ionosphere correction

- **Derived directly from the dual frequency data**
  - **correction computed for the 2 GHz carrier**
  - **relation slightly more complex than for most dual frequency systems**
    - differences in count interval for "old" receivers
    - large inter frequency bias (10-20 µs)
    - takes into account difference in center of phase location

$$I = \frac{V-\beta V'}{1-\alpha^2\beta} - c\,\frac{\delta f_{beacon}}{f_{beacon}}\,\frac{(\eta_2-\eta_1)-\beta(\eta'_2-\eta'_1)}{(1-\alpha^2\beta)\,\Delta T}$$

  - **in practice**
    - the dependency upon the beacon frequency bias is negligible
    - the inter frequency bias does not play a major role
  - **this correction is not exactly the one implemented now**
    - the current formulation leads to results which are incorrect when the frequency bias is not estimated => cannot deliver passes which are completely eliminated

Time determination

- **This is the key difficulty**
  - **the network is not time synchronized as a whole, only two beacons offers time references**
    - a model has to be used to propagate the timing information (fill the gaps)
    - only long term timing is accessible
  - **the quality of the pseudo-range data is poor**
    - precision around 300 m
    - only one frequency transmitted in telemetry
    - asynchronous from phase measurement
  - **reference beacons only provide long term stability**
    - their short term behavior is similar to other beacons
    - their clock behavior is the superposition of short term variablity and long term stability

⇨ **efforts to process orbit and time simultaneously have failed (until now)**

  ⇨ **multi-step approach orbit -> time -> orbit -> time -> orbit !**

Data format issues

- **Measurement principle has changed drastically between generations**
  - **difficult to find common ground between old and "miniaturized" receivers**
    - old receivers: exact integer phase, uncertain time
    - miniaturized receivers: exact times, uncertainty on phase
  - **the current format is one of the only good compromises**
    - moving to a "rawer" format wil probably generate a schism
- **The relation between on-board time and TAI is a key concern**
  - **it is computed relatively late (during POE processing)**
  - **it depends upon the arc over which it has been computed**
    - thus it exhibits discontinuities and breaks in slope at arc boundaries

The RINEX data format

- An old issue ! But receiver independence is truly required now with all the generations of receivers in flight
- GPS-like Doppler version proposed two years ago
  - problem with timing information (but new solution proposed)
  - looses editing and correction informations
  - not suited for new receivers (fields for opening and closing offsets are not needed)
  - limited interest from the users group which met at CNES
- New receivers are better suited for phase GPS-like format
  - as long as continuous tracking remains in effect
  - requires different files for phase and pseudo-range measurements
  - no editing and correction informations
- Handling of meteo data is difficult
  - ideally reuse RINEX MET format with combination of all satellite for a given day
  - difficult to produce and to use

Conclusion

- The difficulties in defining a data format reflect the inherent processing difficulties
  - the data are not self sufficient: a model has to be used to produce timing information
  - timing and orbit cannot easily be solved for in a single step
- The key defficiency of the current format has to do with how this timing/frequency issue is handled
  - it can only be solved if users perform their own timing solutions (adapted to their processing strategy)
  - are users ready to go through this added burden ?
- Adding the timing correction and pseudorange data on the side could be the solution
  - but will any one really process the added information ?
- Everything else is details that can easily be fixed
  - chronological sorting versus passes, day files versus cycles, etc.