
 <b>gAGE/UPC</b>	<b>Proposal to ESA on “ESA Real Time Ionospheric Continental Caster (e-RTICC) for high precision applications” in response to AO/1-9797/19/NL/AF</b>	Issue /Rev	0.0/0.0
		Date	01/07/2022
	Document: Executive_Summary.docx	Page	1 / 7

**Executive Summary**    **DOC. No**  
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**Ionosphere for a High Accuracy Service (IONO4HAS)**    **ACTIVITY**  
**4000128823/19/NL/AS**    **PROJECT REF**  
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# Executive Summary

**ESA Contract No. 4000128823/19/NL/AS**

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		Date	01/07/2022
	Document: Executive_Summary.docx	Page	2 / 7

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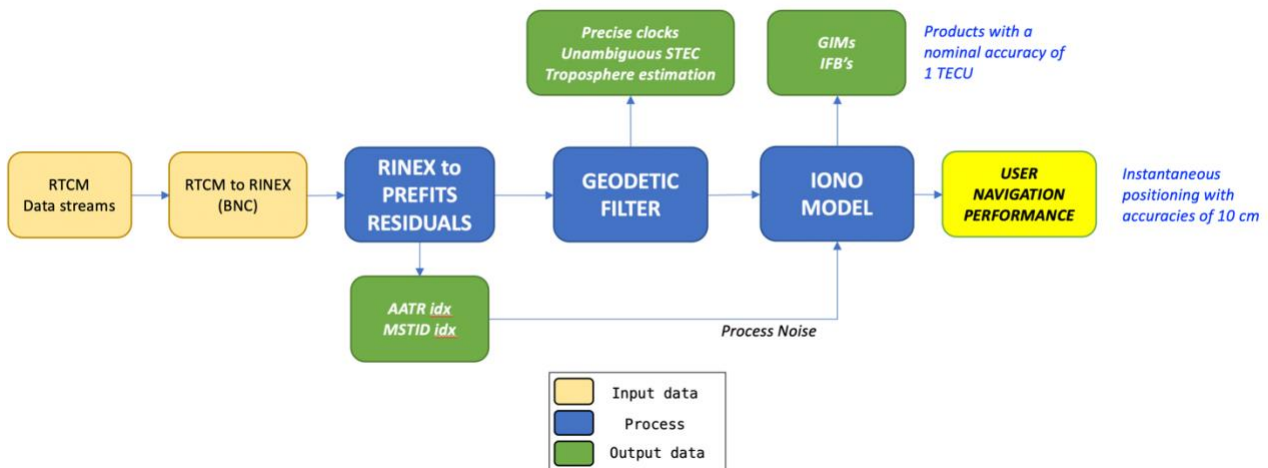
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	Proposal to ESA on “ <b>ESA Real Time Ionospheric Continental Caster (e-RTICC) for high precision applications</b> ” in response to AO/1-9797/19/NL/AF	Issue /Rev	0.0/0.0
		Date	01/07/2022
	Document: Executive_Summary.docx	Page	3 / 7

# 1. Introduction

IONO4HAS is the response of gAGE/UPC group to the “ESA Real Time Ionospheric Continental Caster (e-RTICC) for high precision applications”, AO/1-9797/19/NL/AF. The goal of this project is to develop a prototype able to provide real time ionospheric corrections at continental scale.


To this end, it has been developed a set of modules which are able to gather data in real time, from different streams of data, and, processing this data, to compute a real time ionospheric model with enough accuracy for HAS. The more relevant modules of IONO4HAS are depicted in the following figure:



1. RINEX to Prefits: converts the RINEX observation data obtained in real-time to the prefits format (measurements corrected from the known effects).
2. Geodetic Filter: computes the phase biases, satellite clocks and the zenith tropospheric delay at the receivers.
3. Ionospheric Module: computes the parameters of the ionospheric model: VTEC at IGP's with the corresponding formal errors and DCBs.

# 2. IONO4HAS performance

In order to show the performance of the IONO4HAS tool we present a compliance matrix of the requirements established in the Statement of Work (SoW), where the background colour indicates if the requirement has been totally fulfilled (green) or if there are some issue about the fulfilment (orange).

	Proposal to ESA on “ <b>ESA Real Time Ionospheric Continental Caster (e-RTICC) for high precision applications</b> ” in response to AO/1-9797/19/NL/AF	Issue /Rev	0.0/0.0
		Date	01/07/2022
	Document: Executive_Summary.docx	Page	4 / 7

**Table 1: High level requirements**


REQUIREMENT		Final implementation
ID	Wording	
REQ-HLR-0010	The objective of this activity is the development of a prototype tool for Real-Time 3D ionosphere corrections, e-RTICC	Agreed.
REQ-HLR-0020	The e-RTICC shall be able to process Galileo and GPS satellites.	The current implementation of IONO4HAS works with GPS and Galileo dat, but it is able to work also with data from Beidou, Glonass or QZSS. It depends on the predicted orbits availability
REQ-HLR-0030	The e-RTICC may be able to optionally process Beidou.	
REQ-HLR-0040	The e-RTICC may be able to optionally process GLONASS.	

**Table 2: Functional requirements**


REQUIREMENT		Final implementation
ID	Wording	
REQ-FUN-0010	The e-RTICC shall be modular; each calculation step shall be independent from previous one.	IONO4HAS works in a modular way
REQ-FUN-0020	The e-RTICC shall be able to connect to private/public stream of data.	IONO4HAS works with data from public streams of data
REQ-FUN-0030	The e-RTICC shall be able to use simultaneously several streams of data.	The tool combines data from seven different casters
REQ-FUN-0040	The e-RTICC shall be able to be deployed with minimum intervention (i.e. Virtual Machine, Dock, RPM or similar technologies)	The installation and deployment of the tool has been iterated with the contractor, and the corresponding feedback has been implemented.
REQ-FUN-0050	The e-RTICC shall be used with RINEX data for testing purposes.	The input module works with data in RINEX-v3 format.
REQ-FUN-0060	The e-RTICC shall be used as post-process tool.	IONO4HAS is able to work also in post-process mode and with backward process.
REQ-FUN-0070	The e-RTICC shall be able to introduce new ionosphere/biases messages in a modular way.	The backwards compatibility of new messages can be taken into account.

**Table 3: Technical requirements**

REQUIREMENT		Final implementation
ID	Wording	
REQ-TEC-0010	The e-RTICC shall process as a minimum L1/E1, L2, L5/E5a, E5B, E5, E6	The IONO4HAS model uses ionospheric delays in TECUs, regardless of the frequencies. So, any pair of frequencies can be selected by the operator.
REQ-TEC-0011	The e-RTICC may process B1, B2, B3	

 <b>gAGE/UPC</b>	Proposal to ESA on “ <b>ESA Real Time Ionospheric Continental Caster (e-RTICC) for high precision applications</b> ” in response to AO/1-9797/19/NL/AF	Issue /Rev	0.0/0.0
		Date	01/07/2022
	Document: Executive_Summary.docx	Page	5 / 7


REQUIREMENT		Final implementation
ID	Wording	
REQ-TEC-0020	The e-RTICC shall be able to process carrier phase data.	IONO4HAS works with carrier phase and pseudorange observables
REQ-TEC-0030	The e-RTICC shall be able to process code pseudorange observables	
REQ-TEC-0040	The e-RTICC shall process the data with a 3D ionosphere model	IONO4HAS consists on a dual-layer model, which takes into account the ionospheric delay produced at different heights
REQ-TEC-0050	The e-RTICC shall produce ionospheric corrections with an error estimate	One of the outputs of IONO4HAS is the VTEC at each IGP with its formal error.
REQ-TEC-0060	The e-RTICC shall produce interfrequency bias products for dual frequency CDMA combinations with an error estimate for (REQ-TEC-0061 to REQ-TEC-0067):	Inter-frequency biases (IFBs) for a pair of two frequency signals is computed, for each constellation, along with VTEC at IGP. The rest of IFB, even absolute values, can be computed from the ionosphere and geometry-free combination.
REQ-TEC-0061	GPS: L1/L2	
REQ-TEC-0062	GPS: L1/L5	
REQ-TEC-0063	GAL: E1/E5a	
REQ-TEC-0064	GAL: E1/E5b	
REQ-TEC-0065	GAL: E1/E5	
REQ-TEC-0066	BDS:B1/B2	
REQ-TEC-0067	BDS:B1/B3	
REQ-TEC-0070	REQ-TEC-0060 biases selection has to be done by the operator. (Not limited to one combination for each system according REQ-TEC-0060).	The operator is able to select any combination of two frequencies to compute the IONO4HAS model.
REQ-TEC-0080	The e-RTICC shall generate message for ionosphere to be broadcast from MEO satellite (400 bit maximum for one satellite, using up to 2 satellites)	For ionosphere and DCBs, it has been defined a message with a length of 1,023 bits which is able to be broadcasted in 30 seconds for European users and 150s for worldwide users
REQ-TEC-0081	The e-RTICC shall generate message for ionosphere to be broadcast from GEO/IGSO satellite (400 bit maximum for one satellite with continuous visibility)	
REQ-TEC-0082	The e-RTICC shall generate message for ionosphere to be broadcast from terrestrial networks ( <i>unlimited</i> bandwidth)	For unlimited bandwidth the total ionospheric model (including DCBs), expands 2Mbits, with a time update of 300s
REQ-TEC-0083	REQ-TEC-0080 to REQ-TEC-0082 shall be user selectable	
REQ-TEC-0090	The e-RTICC shall generate message for interfrequency biases to be broadcast from MEO satellite (400 bit maximum for one satellite, using up to 2 satellites)	

	Proposal to ESA on “ESA Real Time Ionospheric Continental Caster (e-RTICC) for high precision applications” in response to AO/1-9797/19/NL/AF	Issue /Rev	0.0/0.0
		Date	01/07/2022
	Document: Executive_Summary.docx	Page	6 / 7

REQUIREMENT		Final implementation
ID	Wording	
REQ-TEC-0091	The e-RTICC shall generate message for interfrequency biases to be broadcast from GEO/IGSO satellite (400 bit maximum for one satellite with continuous visibility)	
REQ-TEC-0092	The e-RTICC shall generate message for interfrequency biases to be broadcast from terrestrial networks ( <i>unlimited</i> bandwidth)	
REQ-TEC-0093	REQ-TEC-0090 to REQ-TEC-0092 shall be user selectable	
REQ-TEC-0100	e-RTICC shall produce ionosphere data from REQ-TEC-008x with the appropriate sampling, 300 seconds (TBD)	Currently, IONO4HAS is providing ionospheric outputs with an interval of 5 minutes. However, it is possible to diminish the interval by reducing the time interval of the input data. This can be done even for specific regions
REQ-TEC-0110	e-RTICC shall produce interfrequency bias data REQ-TEC-009x with the appropriate sampling, 300 seconds (TBD)	
REQ-TEC-0200	Latency of the end-to-end has to be monitored.	Currently the latency of the ionospheric model is around 30s
REQ-TEC-0210	Latency should be less than 1 minute (95%)	

**Table 4: Validation requirements**

REQUIREMENT		Final implementation
ID	Wording	
REQ-VAL-0010	The e-RTICC shall be validated with independent VTEC data	Ionospheric corrections for HAS require an accuracy of around 1 TECU, while VTEC from altimeters have uncertainties of several TECU, so, it was agreed that it cannot be used as a reference.
REQ-VAL-0020	The e-RTICC shall be validated with STEC post-processed data	This validation is done routinely in IONO4HAS
REQ-VAL-0030	The e-RTICC shall validate the Final Interfrequency Biases against a post-process solution	The proposed IONO4HAS precise mode is designed to perform such kind of comparison.
REQ-VAL-0040	The e-RTICC shall be validated for its impact on single frequency users PVT	The PVT validation is done, automatically, in real time over a selected network of permanent stations with known coordinates treated as rover receivers.
REQ-VAL-0050	The e-RTICC shall be validated for its impact on multi-frequency users PVT	
REQ-VAL-0060	The e-RTICC impact on PVT will be done by means of positioning error	

	Proposal to ESA on “ <b>ESA Real Time Ionospheric Continental Caster (e-RTICC) for high precision applications</b> ” in response to AO/1-9797/19/NL/AF	Issue /Rev	0.0/0.0
		Date	01/07/2022
	Document: Executive_Summary.docx	Page	7 / 7

REQUIREMENT		Final implementation
ID	Wording	
REQ-VAL-0070	The e-RTICC impact on PVT will be done by means of convergence time to a 30 cm (TBD) horizontal, vertical and 3D threshold against its counterpart without the corrections.	Using unambiguous wide lane it is possible to navigate, in well sounded areas, with errors at the level of some decimetres instantaneously

**Table 5: Performance requirements**

REQUIREMENT		Final implementation
ID	Wording	
REQ-PER-0010	The e-RTICC shall compute VTEC with an accuracy better than 1 TECU 95% of time.	In well sounded areas, the prediction of STEC has an error smaller than 1 TECU (95 <sup>th</sup> percentile)
REQ-PER-0020	The e-RTICC shall compute STEC with an accuracy better than 1 TECU 95% of time	
REQ-PER-0030	The e-RTICC shall compute Final Interfrequency Biases with an accuracy better than 1 TECU 95% of time	1 TECU is the required accuracy for the inter-frequency biases. We have shown that the comparison between final and real time estimated DCBs are at this level of accuracy.
REQ-PER-0040	The e-RTICC PVT derived solution shall converge in less than 100 seconds on REQ-VAL-0070	Using unambiguous wide lane, positioning is instantaneous, i.e. don't need convergence time.
REQ-PER-0050	The e-RTICC shall have an availability of 95%	The availability of IONO4HAS products is linked to the availability of data streams