W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

PROJECT PLAN FOR THE EXTENSION OF THE RARS NETWORK TO ADVANCED SOUNDERS

WMO Space Programme

Version 1, July 2009

Document change record

Modification	Version	Date	Validation
First draft for discussion at RARS-IG-3 (Ref: RARS-IGDDS-IG3-Doc06_projectplan)	Draft A	19/01/09	J. Lafeuille
Additions to 3.1, 3.2, section 5 (pilot initiatives), Appendix A1 (IASI channel) and revised timeline reflecting comments from RARS-IG-3 : (Ref: RARS-IGDDS-IG3-Doc06_projectplan_Draft B)	Draft B	11/06/09	J. Lafeuille
Details on pilot implementation and addition on section 3.7 on benefits, based on RARS-IG members' review.	Version 1	10 /07/09	B. Ryan

TABLE OF CONTENTS

1 Introduction

The purpose of this document is to propose an extension of the RARS project to embrace the reception of data from certain advanced sounders.

2 Background

2.1 Current RARS Project

The current WMO RARS project has its roots in the EUMETSAT ATOVS Re-transmission Service (EARS). EARS was initially established in 2002 in response to the requirements of Limited Area NWP modelling over Europe (HIRLAM then ALADIN) whose modelling area exceeded the coverage of a single HRPT station, and whose timeliness constraints were not compatible with the current scheme of global data collection.

By merging the data sets from several HRPT stations EARS enabled the extended coverage and short timeliness requirements of the NWP operators to be met.

In recognition of the very positive impact that EARS data has made to NWP model performance, the Co-ordination Group for Meteorological Satellites (CGMS), at its thirty-second session in May 2004, considered whether the system could be expanded into other Northern Hemisphere regions, and then extended to cover the Southern Hemisphere.

With this aim in mind the CGMS encouraged the WMO Space Programme to contact CGMS members and potential regional participants with a view to forming local consortia to develop Regional ATOVS Re-transmission Services similar to EARS.

Following this encouragement from CGMS, the WMO Space Programme established the RARS Project and, through dedicated workshops and Implementation Group meetings, has facilitated the global extrapolation of the EARS concept; with RARS centres now established in the Asia-Pacific and South American regions. The global coverage of the RARS network is planned to reach 80 % of the surface of the globe by 2010

So far, the focus of the RARS project has been on the re-transmission of ATOVS data. However, user requirements for timely access are not limited to ATOVS, as indicated by Recommendation S5 of the Implementation Plan for the Evolution of the Surface- and Space-based Global Observing System (IP-EGOS), which states: "*S5. LEO data timeliness - More timely data are needed to improve utilization, especially in NWP. Improved communication and processing systems should be explored to meet the timeliness requirements in some applications areas (e.g., Regional and Global NWP).*"

As additional instruments have become available through new-generation satellites such as Metop and FY-3, the idea has emerged to collect and re-transmit other data using the same concept. EUMETSAT has initiated pilot activities for the concentration and distribution of ASCAT, IASI and AVHRR data.

Taking into account the high impact of advanced sounding data on NWP, and in response to the recommendation of the International TOVS Study Conference (ITSC), the RARS Implementation Group has proposed to investigate, as a matter of priority, the inclusion of advanced sounder data within the RARS concept.

2.2 User Requirements for Timely Access to Advanced Sounder Data

2.2.1 CrIS and ATMS from NPP/NPOESS

To facilitate the early use of Cross-track Infrared Sounder (CrIS) data by the NWP user community, the ITSC has recommended that the RARS concept be extended to encompass such data.

This request has been made in the knowledge that the SafetyNet will not be available for the collection and re-transmission of data from the precursor mission NPOESS Preparatory Programme (NPP), and that by time of the launch of NPOESS C1, the SafetyNet will have only been partially implemented (with only 2 of the 14 SafetyNet Stations planned to be operational - McMurdo and Svalbard). Therefore, only the direct broadcast capability of NPP and NPOESS-C1 will allow timely access to this data in the 2010 to approximately 2016 time frame. The same consideration applies to the Advanced Technology Microwave Sounder (ATMS).

In the longer term (i.e. post-launch of NPOESS C2) it should not be necessary to re-transmit NPOESS data via the RARS network if, at this stage, the SafetyNet has been fully implemented.

So, any extension to the RARS network to encompass CrIS and ATMS data, should be viewed as a gap-filler, until data timeliness can be ensured through the SafetyNet.

2.2.2 IASI

In response to user requirements, mainly from the European NWP user community, EUMETSAT has recently upgraded the EARS network to include the re-transmission of IASI data from a subset of its EARS stations.

Following a failure of the HRPT transponder onboard Metop-A, Direct Broadcast from Meteop-A was initially suspended, and then reactivated only for portions of the descending orbit that include a large part of the EARS coverage. The handling of IASI data is being organized by EUMETSAT as a pilot activity of EARS. Bearing the above in mind, there is no point at this stage to initiate a global project for IASI. The situation shall be reviewed in advance of the launch of Metop-B.

2.2.3 Other Sounders

FY-3A was launched in May 2008 and includes an IR and MW sounding capability (IRAS, MWTS, MWHS) and a direct readout capability in X-band and L-band (MPT, AHRPT).

Whilst recognizing that FY-3A is an experimental satellite of a new series, it has been proposed by the NWP user community that, once this data becomes available on an operational basis, steps are taken to extend the RARS concept to FY-3A sounding data.

3 Project Goal and Activities

It is proposed that, at this stage, the extension of the RARS network is targeted at the extrapolation of the RARS concept to the re-transmission of NPP/NPOESS CrIS and ATMS data; with the aim of having this capability in place from the launch of NPP until the full implementation of SafetyNet (i.e. 2010-2016 according to the current planning).

Extensions of the RARS concept to include re-transmissions from other sounders (e.g. Metop/IASI and FY-3A) would only be decided after a further review of the issues.

In order to achieve this goal, a number of high-level activities have been identified:

- Refine User Requirements;
- Upgrade/Establish Reception Stations;
- Upgrade Communications Infrastructure (as necessary);
- Optimize the Data Processing and Collection Architecture;
- Ensure Availability of Instrument Data Processing Packages;
- Update RARS Operator Standards;
- Quantification of the Benefits of the RARS Network Extension;
- Ensure User Awareness of Advanced Sounder Service;
- Project Governance.

3.1 Refine User Requirements

Currently the user requirements expressed by NWP operators are at a rather high level. In order to ensure that the RARS network is evolved in an appropriate manner that meets the user needs, further details are required.

3.1.1 Gather Detailed User Requirements

The first step in the further detailing of the user requirements will be to ascertain which NWP operators are interested in processing CrIS and ATMS data in the relevant period (i.e. 2010 to 2016 according to current planning).

For each NWP operator indicating such an interest, more detailed requirement information will be collected, such as:

- Timeframe of interest;
- Timeliness Requirements (by default, assumed to be 30 minutes as per current RARS network);
- Regions of interest;
- Types of data sets of interest (e.g. required channels, full data or principle components, ancillary data, etc);
- Data level;
- Preferred data reception mechanism and limitations;
- Preferred data format.

As an aid to this activity, the 366 IASI channels selected for re-transmission over EARS are identified in Appendix A.1.

3.1.2 Consolidate User Requirements

Once all the detailed user requirements have been gathered, they will be synthesised and consolidated in order to derive, if possible, a common characterisation of the service that will be provided across the network. Once consolidated, these proposed user requirements will be presented to the NWP operators, who expressed an interest in receiving the data (see section 3.1.1) for review and endorsement.

Once reviewed by the relevant NWP operators it is envisaged that the user requirements will undergo a wider review cycle involving:

- APSDEU and NAEDEX (probably via email);
- the RARS Implementation Group;
- the International TOVS Working Group (ITWG).

It is also envisaged that further entities could be added to this review process as appropriate.

WMO standards for data encoding and representation will be used as far as practical.

The requirements will be updated if necessary in the light of the initial implementation of a “pilot” network.

3.2 Upgrade/Establish Reception Stations

The purpose of this activity is to define and establish a reception network that meets the needs of the user community, taking advantage as appropriate of the proven capabilities of the RARS network.

To establish an appropriate reception network a number of discrete activities are foreseen:

i) Identify future operators of stations able to receive data from CrIS and ATMS (in X-band). Investigation will include current RARS operators as well as other potential operators based on information to be sought e.g. from the NASA Direct Readout Laboratory and the NPOESS Direct Readout Mission;

ii) Select potential X-band reception stations on the basis of:

- capability to fulfil the detailed user requirements (produced as a result the activities described in section 3.1);
- the need to optimise coverage of key areas, and minimise overlaps;
- the viability of communications mechanisms for delivering the data to the interested NWP centres (as addressed in section 3.3);
- reliability and sustainability.

A network based on current RARS operators will be considered in the first instance and complemented if appropriate by other operators in order to meet the coverage requirements.

iii) Following the analysis of potential X-band reception stations, agree the baseline set of reception stations.

When agreeing the baseline set of reception stations it is noted that the handling of this data is likely to involve considerably higher volumes than for ATOVS; with a noticeable impact on the processing, network and telecommunications infrastructure cost.

With the above in mind, and noting the limited duration of the project, there is a need to balance the cost of the network with its potential benefits. It is emphasized that global reception coverage is not a mandatory requirement because of the demonstration character of the NPP mission, and the limited time frame envisaged for the operation of this RARS network. It is expected that optimization will be achieved by:

- selecting reception stations with a non-overlapping coverage,
- giving priority to the regions where sounding data have the greatest impact on NWP.

It is envisaged that the service would be based on around 12 – 20 HRPT stations with non-overlapping coverage - the typical coverage of a reception station is around 4% of the globe.

iv) Upgrade, or establish, the agreed set of X-band reception stations.

In preparation for this project, some informal communications have taken place with RARS operators and a provisional list of possible X-band reception stations (together with an indicative coverage map) is provided in Appendix A.2.

3.3 Upgrade Communications Infrastructure

In order to provide the advanced sounder data to the NWP users, it is anticipated that some upgrades to the communications infrastructure may be required. In order to achieve this, the following generic steps are envisaged:

i) Analyse the implications on the communications infrastructure of meeting the user requirements (defined as a result of the activities described in section 3.1) with the baseline network of reception stations (defined as a result of the activities described in section 3.2). Also, taking due account of the results of the optimization of the data collection and processing architecture (see section 3.4).

ii) Identify and implement modifications to the communications infrastructure as appropriate.

It is anticipated that part of the network will be identified to serve as a pilot in order to allow these modifications to be implemented in two steps:

Step a): would involve the communication modifications necessary to implement the Pilot Network;

Step b): would involve the communication modifications necessary to achieve the full extension of the RARS network (following the successful demonstration of the Pilot Network).

3.4 Optimize the Data Collection and Processing Architecture

The data collection and processing architecture shall be optimized, including the definition of the processing to be performed at the local and regional levels**,** in order to ensure operational reliability and cost-efficiency. Several options shall be investigated:

- an architecture similar to the current RARS, where data are concentrated at regional nodes and distributed without the removal of overlaps;
- a variant of the current architecture with an active role of the regional node in the removal of overlaps;
- an architecture similar to the EARS pilot AVHRR project, with a line-by-line acquisition planning ensuring no overlaps between neighbouring stations;
- a simulcast–based architecture relying on a data server.

3.5 Ensure Availability of Instrument-specific Data Processing Packages

The purpose of this activity is to make sure that the instrument-specific data processing packages are made available in a timely manner so that potential users can fully exploit the data from the advanced sounders.

The general assumption (to be confirmed) is that the processing will rely on a combination of the International Polar Orbiter Processing Package (IPOPP[1]) [made available by NASA, the University of Wisconsin, and the Integrated Program Office (IPO)] and AAPP. A possible relationship between the AAPP and IPOPP packages (together with some questions relating to user requirements) has been provided by the NWP SAF and is included in Appendix A.3.

3.6 Update RARS Operator Standards

It is anticipated that an update to the RARS Operator Standards will be required in order to reflect the extension to the services offered by the RARS Network (particularly with respect to the data to be disseminated and its associated monitoring).

3.7 Quantification of the Benefits of the RARS Network Extension

During the course of the Project, the benefits of extending the RARS network will be assessed (possibly through NWP impact studies).

This assessment will be carried out in two parts:

- assessment of the benefits of the Pilot Network (following its implementation – see section 3.3);
- assessment of the benefits of the full implementation of the RARS Network extension.

3.8 Ensure User Awareness of Advanced Sounder Service

The purpose of this activity is to ensure that potential users of the service are provided with timely information about the availability of the service.

It is anticipated that users will be kept informed via a number of means, including:

- targeted emails to the interested NWP centres;
- updates to the WMO RARS website;

[1] As of early 2009, IPOPP is available as an alpha release which is thought to be capable of processing only EOS data. A beta release is expected during 2010. The data formats have not yet been released – which is a pre-requisite for the companion development of AAPP. IPOPP may require a more powerful machine than is commonly used at RARS nodes for running AAPP.

- regular briefings to inter-regional data exchange meetings, i.e. North America-Europe Data Exchange meeting (NAEDEX) and Asia-Pacific Satellite Data Exchange and Utilization meeting (APSDEU);
- information made available to the International TOVS Study Conference (ITSC) – including any results concerning the quantification of the benefits of the extension of the RARS network (see section 3.7) ;
- information flow to Regional Rapporteurs on Space Matters.

3.9 Project Governance

The Terms of Reference and Membership of the RARS Implementation Group will be reviewed and updated as appropriate in order to reflect the new scope of the project.

Attention will be paid to schedule control, in order to deliver the service during the target period, i.e. starting with the launch of NPP until the full availability of the SafetyNet and of the associated redistribution mechanisms to the user community.

Close coordination shall be maintained with the IPO in order to adapt to any schedule change of the NPP and NPOESS programmes.

Care will also be taken to ensure the continuing availability of the current ATOVS service during the execution of this project.

4 Schedule of Activities and Implementation Responsibilities

ACTIVITY/MILESTONE	Lead	Support	H2 2009	H1 2010	H2 2010	H1 2011	H2 2011
Milestones							
Events/Meetings			K-off	IG-4 ITWG-17	IG-5	IG-6	Operations Start
1. Refinement of User Requirements							
1.1 Gathering of Detailed User Requirements	WMO SP	RARS Ops					
1.2 Consolidation of User Requirements	WMO SP	RARS Ops					
1.3 Update of requirements after pilot phase							
2. Upgrade/Establishment of Reception Stations							
2.1 Identification of Possible Reception Stations	WMO SP	RARS Ops					
2.2 Analyse Compatibility of Possible Reception Stations	WMO SP	RARS Ops					
2.3 Agree Baseline Set of Reception Stations	RARS-IG			Initial	Final		
2.4 Upgrade, or Establish, Reception Stations	RARS Ops	WMO SP					
3. Upgrade/Establishment of Communications Infrastructure							
3.1 Analyse Implications of Meeting User Requirements with Reception Station Baseline	RARS Ops	WMO SP					
3.2a) Identify and Implement Modifications to Communications Infrastructure (Pilot network)	RARS Ops						
3.2b) Modifications to Communications (whole)	RARS Ops						
4. Optimise the Data Processing and Collection Architecture	RARS Ops	WMO SP					
5. Ensure Availability of Instrument-specific Data Processing Packages	WMO SP	RARS Ops					
6. Update RARS Operator Standards	WMO SP	RARS Ops					
7. Ensure User Awareness of Service	WMO SP	RARS Ops					
8. Project Governance	RARS-IG	WMO SP					
9. Start of Operations							

5 Related Pilot Initiatives

A number of related initiatives are underway which could be expected to bring benefits to this initiative; particularly as a technology demonstrator.

These pilot projects, underway in three countries, generally involve the use of AIRS data and the IMAPP package for processing.

A short description of these pilot projects, and their implementation status as of early 2009, is given below.

5.1 Report from Australia (BoM)

AIRS data has been successfully processed through to BUFR format using the IMAPP package and the additional software, as announced on 25 March 2009. We plan to test these data in our NWP system but this will not occur for several months.

Our X-band network is still incomplete but a contract has just been signed for installation of the final system in Darwin. These works should be completed by July 2009. Once the network is in place, we plan to install processing computers at each site which will generate the lower volume BUFR products. These files will then be sent to Melbourne for use in our NWP system, and we would be happy to make these data available for other users as part of a pilot study (possibly via ftp). The same processing systems (however, using IPOPP) will be used for CrIS processing after the launch of NPP.

5.2 Report from Brazil (INPE)

Efforts are already underway to insert AIRS sounding data into the RARS network. (end-2009 could be a feasible target to complete this effort). AIRS data has been successfully processed to level L1b using the external IMAPP package.

The further implementation of this pilot project is being coordinated with BoM and the NWP SAF.

5.3 Report from Argentina (SMN and CONAE)

At present, the Marambio Station has the capability to process AIRS data but, because of bandwidth limitations, does not have the capability to insert this data on the RARS network. It is planned to increase the bandwidth during 2009; thereby enabling Argentina to contribute to the pilot project.

6 List of acronyms

ADM	Advanced Dissemination Methods
AIRS	Atmospheric Infrared Sounder
ATMS	Advanced Technology Microwave Sounder
ATOVS	Advanced TIROS Operational Vertical Sounder
CBS	Commission of Basic Systems
CGMS	Coordination Group of Meteorological Satellites
CM	Consultative Meetings on High-level Policy on Satellite Matters
CrIS	Cross-track Infrared Sounder
DCPC	Data Collection or Product Centre (WIS)
DVB-S	Digital Video Broadcast by Satellite
EC	Executive Council
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems (GEO)
GISC	Global Information System Centre (WIS)
IP	Internet Protocol
IGDDS	Integrated Global Data Dissemination Service
IGDDS-IG	IGDDS Implementation Group
IPO	Integrated Program Office
IPOPP	International Polar Orbiter Processing Package
ISO	International Standards Organization
OSI	Open Systems Interconnection (ISO)
QOS	Quality of Service
RARS	Regional ATOVS Retransmission Service
RARS-IG	RARS Implementation Group
WIS	WMO Information System
WSP	WMO Space Programme
WSP-IP	WMO Space Programme Implementation Plan

A.1 IASI Channels Selected for Re-transmission using EARS

	IASI Chan.	σ (cm-1)	λ (μm)
1	16	648.75	15.414
2	38	654.25	15.285
3	49	657.00	15.221
4	51	657.50	15.209
5	55	658.50	15.186
6	57	659.00	15.175
7	59	659.50	15.163
8	61	660.00	15.152
9	63	660.50	15.140
10	66	661.25	15.123
11	70	662.25	15.100
12	72	662.75	15.089
13	74	663.25	15.077
14	79	664.50	15.049
15	81	665.00	15.038
16	83	665.50	15.026
17	85	666.00	15.015
18	87	666.50	15.004
19	89	667.00	14.993
20	92	667.75	14.976
21	95	668.50	14.959
22	97	669.00	14.948
23	99	669.50	14.937
24	101	670.00	14.925
25	104	670.75	14.909
26	106	671.25	14.898
27	109	672.00	14.881
28	111	672.50	14.870
29	113	673.00	14.859
30	116	673.75	14.842
31	119	674.50	14.826
32	122	675.25	14.809
33	125	676.00	14.793
34	128	676.75	14.777
35	131	677.50	14.760
36	133	678.00	14.749
37	135	678.50	14.738
38	138	679.25	14.722
39	141	680.00	14.706
40	144	680.75	14.690
41	146	681.25	14.679
42	148	681.75	14.668

	IASI Chan.	σ (cm-1)	λ (μm)
43	151	682.50	14.652
44	154	683.25	14.636
45	157	684.00	14.620
46	159	684.50	14.609
47	161	685.00	14.599
48	163	685.50	14.588
49	165	686.00	14.577
50	167	686.50	14.567
51	170	687.25	14.551
52	173	688.00	14.535
53	176	688.75	14.519
54	178	689.25	14.509
55	179	689.50	14.503
56	180	689.75	14.498
57	183	690.50	14.482
58	185	691.00	14.472
59	187	691.50	14.461
60	189	692.00	14.451
61	191	692.50	14.440
62	193	693.00	14.430
63	195	693.50	14.420
64	197	694.00	14.409
65	199	694.50	14.399
66	201	695.00	14.388
67	203	695.50	14.378
68	205	696.00	14.368
69	207	696.50	14.358
70	210	697.25	14.342
71	212	697.75	14.332
72	214	698.25	14.322
73	217	699.00	14.306
74	219	699.50	14.296
75	222	700.25	14.281
76	224	700.75	14.270
77	226	701.25	14.260
78	228	701.75	14.250
79	230	702.25	14.240
80	232	702.75	14.230
81	234	703.25	14.220
82	236	703.75	14.210
83	239	704.50	14.194
84	241	705.00	14.184
85	242	705.25	14.179
86	243	705.50	14.174
87	246	706.25	14.159
88	249	707.00	14.144
89	252	707.75	14.129

	IASI Chan.	σ (cm-1)	λ (μm)
90	254	708.25	14.119
91	256	708.75	14.109
92	258	709.25	14.099
93	260	709.75	14.089
94	262	710.25	14.080
95	265	711.00	14.065
96	267	711.50	14.055
97	269	712.00	14.045
98	271	712.50	14.035
99	272	712.75	14.030
100	273	713.00	14.025
101	275	713.50	14.015
102	278	714.25	14.001
103	280	714.75	13.991
104	282	715.25	13.981
105	284	715.75	13.971
106	286	716.25	13.962
107	288	716.75	13.952
108	290	717.25	13.942
109	292	717.75	13.932
110	294	718.25	13.923
111	296	718.75	13.913
112	299	719.50	13.899
113	301	720.00	13.889
114	303	720.50	13.879
115	306	721.25	13.865
116	308	721.75	13.855
117	310	722.25	13.846
118	312	722.75	13.836
119	314	723.25	13.826
120	316	723.75	13.817
121	318	724.25	13.807
122	320	724.75	13.798
123	323	725.50	13.784
124	325	726.00	13.774
125	327	726.50	13.765
126	329	727.00	13.755
127	331	727.50	13.746
128	333	728.00	13.736
129	335	728.50	13.727
130	337	729.00	13.717
131	339	729.50	13.708
132	341	730.00	13.699
133	343	730.50	13.689
134	345	731.00	13.680
135	347	731.50	13.671
136	350	732.25	13.657

	IASI Chan.	σ (cm-1)	λ (μm)
137	352	732.75	13.647
138	354	733.25	13.638
139	356	733.75	13.629
140	358	734.25	13.619
141	360	734.75	13.610
142	362	735.25	13.601
143	364	735.75	13.592
144	366	736.25	13.582
145	369	737.00	13.569
146	371	737.50	13.559
147	373	738.00	13.550
148	375	738.50	13.541
149	377	739.00	13.532
150	379	739.50	13.523
151	381	740.00	13.514
152	383	740.50	13.504
153	386	741.25	13.491
154	389	742.00	13.477
155	398	744.25	13.436
156	401	745.00	13.423
157	404	745.75	13.409
158	407	746.50	13.396
159	410	747.25	13.382
160	414	748.25	13.365
161	416	748.75	13.356
162	426	751.25	13.311
163	428	751.75	13.302
164	432	752.75	13.285
165	434	753.25	13.276
166	439	754.50	13.254
167	445	756.00	13.228
168	457	759.00	13.175
169	515	773.50	12.928
170	546	781.25	12.800
171	552	782.75	12.775
172	559	784.50	12.747
173	566	786.25	12.719
174	571	787.50	12.698
175	573	788.00	12.690
176	646	806.25	12.403
177	662	810.25	12.342
178	668	811.75	12.319
179	756	833.75	11.994
180	867	861.50	11.608
181	906	871.25	11.478
182	921	875.00	11.429
183	1027	901.50	11.093

	IASI Chan.	σ (cm-1)	λ (μm)
184	1046	906.25	11.034
185	1090	917.25	10.902
186	1121	925.00	10.811
187	1133	928.00	10.776
188	1191	942.50	10.610
189	1194	943.25	10.602
190	1271	962.50	10.390
191	1479	1014.50	9.857
192	1509	1022.00	9.785
193	1513	1023.00	9.775
194	1521	1025.00	9.756
195	1536	1028.75	9.721
196	1574	1038.25	9.632
197	1578	1039.25	9.622
198	1579	1039.50	9.620
199	1585	1041.00	9.606
200	1587	1041.50	9.602
201	1626	1051.25	9.512
202	1639	1054.50	9.483
203	1643	1055.50	9.474
204	1652	1057.75	9.454
205	1658	1059.25	9.441
206	1671	1062.50	9.412
207	1786	1091.25	9.164
208	1805	1096.00	9.124
209	1884	1115.75	8.963
210	1946	1131.25	8.840
211	1991	1142.50	8.753
212	2019	1149.50	8.699
213	2094	1168.25	8.560
214	2119	1174.50	8.514
215	2213	1198.00	8.347
216	2239	1204.50	8.302
217	2245	1206.00	8.292
218	2271	1212.50	8.247
219	2321	1225.00	8.163
220	2398	1244.25	8.037
221	2701	1320.00	7.576
222	2741	1330.00	7.519
223	2745	1331.00	7.513
224	2819	1349.50	7.410
225	2889	1367.00	7.315
226	2907	1371.50	7.291
227	2910	1372.25	7.287
228	2919	1374.50	7.275
229	2939	1379.50	7.249
230	2944	1380.75	7.242

	IASI Chan.	σ (cm-1)	λ (μm)
231	2948	1381.75	7.237
232	2951	1382.50	7.233
233	2958	1384.25	7.224
234	2977	1389.00	7.199
235	2985	1391.00	7.189
236	2988	1391.75	7.185
237	2991	1392.50	7.181
238	2993	1393.00	7.179
239	3002	1395.25	7.167
240	3008	1396.75	7.159
241	3014	1398.25	7.152
242	3027	1401.50	7.135
243	3029	1402.00	7.133
244	3036	1403.75	7.124
245	3047	1406.50	7.110
246	3049	1407.00	7.107
247	3053	1408.00	7.102
248	3058	1409.25	7.096
249	3064	1410.75	7.088
250	3069	1412.00	7.082
251	3087	1416.50	7.060
252	3093	1418.00	7.052
253	3098	1419.25	7.046
254	3105	1421.00	7.037
255	3107	1421.50	7.035
256	3110	1422.25	7.031
257	3127	1426.50	7.010
258	3136	1428.75	6.999
259	3151	1432.50	6.981
260	3160	1434.75	6.970
261	3165	1436.00	6.964
262	3168	1436.75	6.960
263	3175	1438.50	6.952
264	3178	1439.25	6.948
265	3207	1446.50	6.913
266	3228	1451.75	6.888
267	3244	1455.75	6.869
268	3248	1456.75	6.865
269	3252	1457.75	6.860
270	3256	1458.75	6.855
271	3263	1460.50	6.847
272	3281	1465.00	6.826
273	3303	1470.50	6.800
274	3309	1472.00	6.793
275	3312	1472.75	6.790
276	3322	1475.25	6.779
277	3339	1479.50	6.759

	IASI Chan.	σ (cm-1)	λ (μm)
278	3375	1488.50	6.718
279	3378	1489.25	6.715
280	3411	1497.50	6.678
281	3438	1504.25	6.648
282	3440	1504.75	6.646
283	3442	1505.25	6.643
284	3444	1505.75	6.641
285	3446	1506.25	6.639
286	3448	1506.75	6.637
287	3450	1507.25	6.635
288	3452	1507.75	6.632
289	3454	1508.25	6.630
290	3458	1509.25	6.626
291	3467	1511.50	6.616
292	3476	1513.75	6.606
293	3484	1515.75	6.597
294	3491	1517.50	6.590
295	3497	1519.00	6.583
296	3499	1519.50	6.581
297	3504	1520.75	6.576
298	3506	1521.25	6.574
299	3509	1522.00	6.570
300	3518	1524.25	6.561
301	3522	1525.25	6.556
302	3527	1526.50	6.551
303	3540	1529.75	6.537
304	3555	1533.50	6.521
305	3575	1538.50	6.500
306	3577	1539.00	6.498
307	3580	1539.75	6.495
308	3582	1540.25	6.492
309	3586	1541.25	6.488
310	3589	1542.00	6.485
311	3599	1544.50	6.475
312	3645	1556.00	6.427
313	3653	1558.00	6.418
314	3658	1559.25	6.413
315	3661	1560.00	6.410
316	3943	1630.50	6.133
317	4032	1652.75	6.051
318	5130	1927.25	5.189
319	5368	1986.75	5.033
320	5371	1987.50	5.031
321	5379	1989.50	5.026
322	5381	1990.00	5.025
323	5383	1990.50	5.024
324	5397	1994.00	5.015

	IASI Chan.	σ (cm-1)	λ (μm)
325	5399	1994.50	5.014
326	5401	1995.00	5.013
327	5403	1995.50	5.011
328	5405	1996.00	5.010
329	5455	2008.50	4.979
330	5480	2014.75	4.963
331	5483	2015.50	4.962
332	5485	2016.00	4.960
333	5492	2017.75	4.956
334	5502	2020.25	4.950
335	5507	2021.50	4.947
336	5509	2022.00	4.946
337	5517	2024.00	4.941
338	5558	2034.25	4.916
339	5988	2141.75	4.669
340	5992	2142.75	4.667
341	5994	2143.25	4.666
342	6003	2145.50	4.661
343	6350	2232.25	4.480
344	6458	2259.25	4.426
345	6463	2260.50	4.424
346	6601	2295.00	4.357
347	6962	2385.25	4.192
348	6978	2389.25	4.185
349	6980	2389.75	4.185
350	6982	2390.25	4.184
351	6985	2391.00	4.182
352	6987	2391.50	4.181
353	6989	2392.00	4.181
354	6991	2392.50	4.180
355	6993	2393.00	4.179
356	6995	2393.50	4.178
357	6997	2394.00	4.177
358	7001	2395.00	4.175
359	7267	2461.50	4.063
360	7269	2462.00	4.062
361	7389	2492.00	4.013
362	7424	2500.75	3.999
363	7426	2501.25	3.998
364	7428	2501.75	3.997
365	7885	2616.00	3.823
366	8007	2646.50	3.779

A.2 Provisional List of Potential X-Band Reception Stations and Coverage Map

The following table summarizes the reception stations that RARS Operators have indicated may participate in the project.

EARS	South American RARS	Asia-Pacific RARS
Lannion	Cachoeira Paulista	Melbourne
Maspalomas	Cuiba	Darwin
Svalbard	Cordoba	Perth
Moscow		Casey
		Townsville

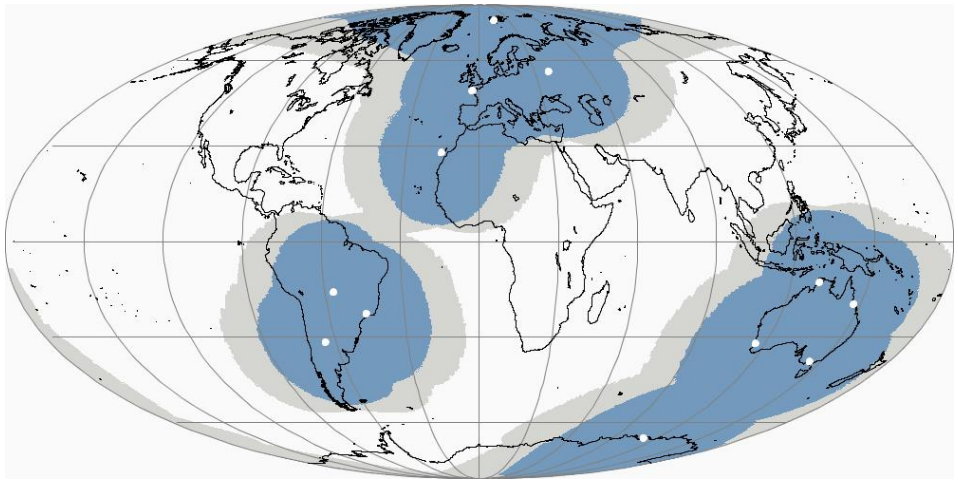

Figure 1: Potential X-Band Reception Coverage (based on expressions of interest)

A.3 Pre-Processing Issues for NPP (Input Provided by NWP SAF)