CoRaSat

COgnitive RAdio for SATellite Communications

FP7-ICT

Collaborative Project - Grant Agreement no.: 316779

Collaborative project

Deliverable D5.6

Final dissemination and exploitation activity report

Project acronym: **CoRaSat**

Project full title: **COgnitive RAdio for SATellite Communications**

Grant agreement no: **316779**

Project web site: **www.ict-corasat.eu**

Deliverable No.		**D5.6**	
Delivery Date		**Month 36**	
Work Package No.	**WP5**	**Work Package Title:**	**Building the CoRaSat exploitation framework**
Authors (Partner) (per Beneficiary, if more than one Beneficiary provide it together)		**Barry Evans, Paul Thompson (UniS)** **Sina Maleki, E. Lagunas, Symeon Chatzinotas, Shree Krishna Sharma (UL)** **Joel Grotz (NTC)** **Alessandro Vanelli-Coralli, Alessandro Guidotti, Daniele Tarchi, Vincenzo Icolari, Giovanni E. Corazza, Carlo Caini (UNIBO)** **Konstantinos Liolis, Jens Krause, Philippe Secher, Jean-Pierre Choffray, Frank Zimmer (SES)** **Nicolas Chuberre (TAS)**	
Status (F: final; D: draft; RD: revised draft):		**F**	
Dissemination level: **PU = Public; PP = Restricted to other program participants; RE = Restricted to a group specified by the consortium; CO = Confidential, only for members of the consortium.**		**PU**	
File Name:		**CoRaSat_Del_D5_6_r1_v0.docx**	
Project start date and duration		**01 October 2012, 36 month**	

INTENTIONALLY LEFT BLANK

TABLE OF CONTENT

1 EXECUTIVE SUMMARY

This deliverable presents the **final dissemination report and actual activities** within the three years of the CoRaSat Project, *i.e.*, dissemination materials elaborated, report on raising awareness activities to relevant stakeholders, and the **exploitation plan for each Partner**. The dissemination material includes journal articles, conference papers, workshops, presentations to regulators, standardization inputs and documents, and general awareness presentations. We also include herein a table that captures **our targets in each category with our success rate** to the end of the project.

From the work in the project, we have published **25 conference papers**, **6 journal papers**, and **a book chapter**, which have **succeeded in getting the awareness of the CoRaSat project** into a wide section of the community. There will be ongoing work within the group to expand on the journal publications post the project end. On a wider readership basis, we have a paper published in a special issue of the **IEEE Communications Magazine**, which will be widely read and enable the project to be seen by a worldwide audience. We have already collaborated in 8 workshops one of which was on cognitive radio at the EuCNC in Bologna in 2014, which gave us exposure to the Cognitive Radio (CR) community. A major success was the acceptance of a **dedicated workshop** for ICC 2015 to focus on CR in satellite and terrestrial systems frequency sharing. The latter attracted 13 papers plus two keynotes and contributed to a successful full day workshop at the IEEE flagship conference. We have also held a **workshop with the ESA** project FREESTONE.

We have presented the project to **6 EU regulators** and this has enabled us to get deeper engagement with them and access data base material. It also resulted in us being invited to join the **CEPT FM 44** group that has now taken our database concept to the point of engaging all EU regulators. Subsequently the CoRaSat work was incorporated into a CEPT SE-40 report, which is currently out for consultation. We have been invited to present at the EU spectrum policy group on geolocation databases and to the UK spectrum policy forum. We have submitted a technical report to the **ETSI SES-SCN group as an SRDoc**, which was published and this is now working its way through updates, which involve the satellite operators and equipment manufacturers. More recently, we have engaged with the **IEEE 1900 standards group** who has this year opened up a new topic in Spectrum database infrastructures/standards and we have contributed to this work.

All of the EU satellite operators have been made aware of the CoRaSat work and the booth that CoRaSat participated in at the EUCNC 2014 meeting enabled us to reach the vast majority of the terrestrial mobile community. The CoRaSat project has had a major impact both in the regulatory arena where it has driven the agenda for sharing of spectrum within CEPT as well as in the satellite industry itself where it has given confidence that the additional shared-band spectrum can be successfully used for future HTS satellite systems.

We also address in this deliverable the longer term plans for exploitation by the partners. This is linked to the technology roadmap presented in D5.1. Success in demonstrating additional spectrum availability for the satellite community has impacts on the design of future satellites as well as terminals and gateways. In addition, the key challenge of acceptability and operation of a database system across Europe has been taken on by the CEPT partly as a result of our work.

2 SCOPE AND STRUCTURE OF THE DOCUMENT

This deliverable presents dissemination activities of the CoRaSat project from 10/2012 to 09/2015, on raising awareness activities to relevant stakeholders, including regulators, satellite and terrestrial operators as well as scientific community and general public. These activities are outlined including journals and conference publications, workshops, tutorials, white papers, panel discussions, contribution to regulation and standardisation initiatives, dissemination activities towards industry-related audiences as well as the general public. Also included are the standards and regulatory dissemination and finally the exploitation plans of the partners.

This deliverable is organised as follows.

Chapter 3 summarizes the original dissemination plan presented in D5.4, including the rationale for the dissemination activities envisaged for CoRaSat, the main dissemination paths, and activities foreseen for the project.

The dissemination achievements of CoRaSat in the first year (10/2012-09/2013), the second year (10/2013-09/2014) and the third year (10/2014-9/2015) are detailed in Chapters 4, 5, and 6 respectively.

Chapter 7 compares overall dissemination outputs with the original plan proposed.

In Chapter 8, following the technology roadmaps presented in D5.1, we present the plans for exploitation by the partners of the project.

Finally, Chapter 9 provides some concluding remarks on the dissemination activities performed during the CoRaSat project.

3 SUMMARY OF PROPOSED DISSEMINATION PLAN

This section summarizes the dissemination plan presented in D5.4 including the main dissemination paths and activities proposed for the project. The dissemination objects proposed in D5.4 mainly include high quality publications at both satellite and terrestrial conferences and top scientific journals, regulators and standardisation bodies, industrial stakeholders as well as general public. Specifically, the main dissemination activities and target areas include the following:

- Submissions to recognised international conferences and magazines from both the satellite and terrestrial domains. This dissemination path will make the satellite community aware of the benefits that the CR principles and concepts can bring to Satellite Communications, and the terrestrial community will be aware of the applicability of CR spectrum co-existence principles in communication scenarios, such as the satellite case, which have received little attention in past CR research. CoRaSat partners will also participate and contribute to relevant, high-profile international conferences, symposia, workshops and summits by submitting technical papers, giving technical presentations and tutorials, showing posters, organising special sessions and/or workshops and presenting the CoRaSat project at exhibitions and other relevant events. The key technical achievements and outputs will be published in referred international specialised journals. Moreover, Submissions to special issues of highly recognised journals are also foreseen and contributions to edited books might be considered as well. High-impact journals from both the satellite and terrestrial domains will be considered so that results and findings of CoRaSat can be taken up and used in future advancements and research. The targeted conferences, journals and magazines are summarized in Table 1.
- Regulators, institutional and governmental bodies will be informed of CoRaSat progress via face-to-face meetings and presentations. Inputs will be provided to EU regulators in the form of advice on how to organise the spectrum co-existence of bands between terrestrial and satellite systems, in order to assist them in spectrum decisions in the various bands and to create awareness of the possibility of CR applicability on Satellite Systems and the increased spectrum efficiency in satellite bands based on CR principles. CoRaSat partners will also contribute to and influence relevant standardisation bodies by promoting and triggering new work items and activities in these bodies. The targeted regulatory and standardisation bodies are summarized in
- Table 2.
- Dissemination to the industrial communities (satellite and terrestrial industrial associations) will be addressed by taking part in relevant events and giving presentations on CoRaSat project results Collaboration with other EU-funded research projects working on CoRaSat-relevant topics will be pursued by means of EC clusters and concentration meetings relevant to the project's objectives. Related FP7 and national projects will be contacted in order to liaise and benefit from mutual outputs. CoRaSat partners will attend relevant dissemination events from other projects. The relevant industry communities listed in D5.4 are summarized in Table 3.
- General articles for the national press will be released in order to awaken the views of scarce spectrum and the ideas of spectrum co-existence in the general public. CoRaSat will maintain a project web site summarising the project objectives and providing regular updates with relevant news, issued (public) deliverables, reports and white papers, which will be made publicly available online.

Table 1- List of targeted Conferences and Journals.

Type of dissemination	Contribution(s)
Conferences on Satellite Communication	Ka and Broadband Communications, Navigation and Earth Observation Conference
	International Communications Satellite Systems Conference (ICSSC)
	Advanced Satellite Multimedia Systems Conference (ASMS)
	International Conference on Advances in Satellite and Space Communications (SPACOMM)
	International Conference on Personal Satellite Services (PSATS)
	International IEEE-AESS conference in Europe about Space and Satellite Communications (ESTEL)
	International conference on Advances in Satellite and Space Communications (SPACOMM)
	European Microwave Conference (EuMC)
Conferences on Terrestrial Wireless Communication	Future Networks and Mobile Summit (FuNeMS)
	IEEE Global Communications Conference (GLOBECOM)
	IEEE International Conference on Communications (ICC)
	IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)
	IEEE Vehicular Technology Conference (VTC)
	European Wireless Conference (EW)
Conferences on Cognitive Radio	IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN)
	International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM)
	IEEE ICC Workshop on Cognitive and Cooperative Networks (CoCoNet5)
	The Second IEEE International Workshop on Emerging COgnitive Radio Applications and aLgorithms (CORAL)
Journals	IEEE Transactions, Journals and Magazines as well as other high-profile specialised publications such as Elsevier, Wiley, EURASIP and Springer journals, including not only open calls but also special issues that are relevant to CoRaSat; Cognitive Radio Series of the IEEE Journal on Selected Areas in Communications; IEEE Magazine or similar.

Table 2 - List of Regulatory and Standardization bodies for dissemination.

Type of community		Dissemination activity
Regulatory Bodies	European regulatory bodies	The European Conference of Postal and Telecommunications Administrations (CEPT)
		The Radio Spectrum Policy Group (RSPG)
		The Radio Spectrum Committee (RSC)

	National regulatory bodies	OFCOM (United Kingdom)
		BNetzA (Germany)
		ANFR and ARCEP (two administrative authorities in France)
		ILR (Luxembourg)
		FUB (Italy)
		BIPT (Belgium)
Standardization bodies		IEEE 802.22 (Enabling Broadband Wireless Access Using Cognitive Radio Technology and Spectrum Sharing in White Spaces)
		IEEE 1900.6 (Spectrum Sensing in Advanced Radio Systems)
		ETSI RRS (Reconfigurable Radio Systems) group
		ETSI Technical Committee SES (in particular the Satellite Communications and Navigation Working group)
		IEEE 802.11,16 (microwave links)
		IEEE 802.19 (coexistence between wireless standards of unlicensed devices)
		IEEE 802.21 (handover and interoperability between heterogeneous network types)
		IEEE 1900.4 (Architecture and Enablers for Optimized Radio & Spectrum resource usage)
		3GPP standards for cellular systems

Table 3 - List of Industry Communities for dissemination.

Type of community	Addressed entity
European Technology Platforms	The Integral SatCom Initiative (ISI)
	the ETP for communications networks and services (Net!Works)
	The Networked & Electronic Media (NEM)
	the ETP dedicated to Software and Services (NESSI)
Industry Groups	The European Satellite Operators' Association (ESOA)
	The European Telecommunications Network Operators' (ETNO) association
	the trade association of the European Space Industry (Eurospace)
National Associations and Technology Platforms	The United Kingdom Industrial Space Committee (UKISC, UK)
	The Space Special Interest Group (SpaceSIG, UK)
	Luxembourg Space Cluster (Luxembourg)
	The Italian Association for Space-based Applications and Services (ASAS, IT)
	The Association of Italian Small and Medium Aerospace Enterprises (AIPAS, IT)
	The National Centre for Space Studies (CNES, FR)

4 YEAR 1 ACTIVITIES

This section presents the dissemination activities and achievements of CoRaSat in the first year, which include journals and conference publications, workshops, tutorials, white papers, panel discussions, contribution to regulation and standardisation initiatives, industry-related audiences and the general public.

4.1 Publications in Conferences and Journals

Table 4 - Publications in conferences and journals in Year 1.

No	Conferences	Title	Authors	Status/Publication details
1	22nd Future Network & Mobile Summit (FUNEMS 2013)	Cognitive Radio Scenarios for Satellite Communications: The CoRaSat Approach [1]	SES: K. Liolis, G. Schlueter, J. Krause, F. Zimmer UL: S. Chatzinotas UNIS: B. Evans UNIBO: A. Guidotti, D. Tarchi,A. Vanelli - Coralli	Lisbon, July 2013, pp1-10, ISBN: 978-1-905824-36-6

4.2 Activities for Regulation and Standardization

Table 5 - Activities for regulations and standardization in Year 1.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	Presentation to UK Regulator (OFCOM)	UNIS	July 2013, London	16 Regulator staff	UK
2	Presentation of the project to Belgium regulatory authorities (BIPT)	NTC	July 2013, Brussels	5 Regulator staff	BEL
3	Meeting with ANFR on CoRaSat	TAS	June 2013, France	Regulators	FR
4	Presentation to CEPT FM-44	UNIS	July 2013, London	Experts	UK

4.3 Activities for Workshops

Table 6 - Activities for workshops in Year 1.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	EU Workshop on CR	TAS	Sep 2013, Lisbon	Scientists and Regulators	EU
2	Participation to the ETSI workshop on reconfigurable radio systems	TAS	Dec 2012, Cannes	Standardizatio n & regulatory, industry stakeholders	EU

3	Presentation of the CoRaSat project and approach at FUNEMS workshop	NTC	July 2013, Lisbon	Scientific and Regulators	ALL
4	COST IC0902	UNIBO/UL	July 2013, London	Academia	ALL

4.4 Activities for Industry dissemination

Table 7 - Activities for industry dissemination in Year 1.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	Presentation to Inmarsat	UNIS	Sep, 2013, London	Operators, industry	ALL
2	Presentation to Avanti	UNIS	Sep, 2013, London	Operators, industry	ALL
3	Presentation to O3b Networks	SES	2013, Luxembourg	Operators, industry	ALL

4.5 Activities for general public dissemination

Table 8 - Activities for general public dissemination in Year 1.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	Concertation meeting	UNIBO	Oct. 2012, Bruxelles	Academia, Industry, Public Bodies	EU
2	Concertation meeting	UNIBO	Feb. 2013, Bruxelles	Academia, Industry, Public Bodies	EU
3	Radio Access spectrum Cluster meeting	UNIBO	July 2013, Lisbon	Academia, Industry, Public Bodies	EU

In year 1, we concentrated on creating an awareness of CR in the satellite and terrestrial community for the CoRaSat project objectives and scenarios under investigation. Of particular note was the presentation to 3 regulators around Europe and the welcome acceptance of the work that we were doing. This led to an invitation to join the CEPT group FM44 to which CoRaSat has now contributed and their take up of the data base ideas proposed by CoRaSat in their documentation. The early introduction of a technical report into ETSI standards was also a notable achievement, which created awareness with operators and manufacturers of the project work. The satellite approach was new to the CR community and we also succeeded in creating an awareness of this new approach in this fora.

The output of scientific papers was low in this first year and this is common for a project addressing a new area, but by the end of the year we had a number of papers accepted into conferences, and these appear in the year 2 report.

5 YEAR 2 ACTIVITIES

This section presents the dissemination activities and achievements of CoRaSat in the second year, which include journal and conference publications, workshops, tutorials, white papers, panel discussions, contribution to regulation and standardisation initiatives, industry-related audiences and the general public.

5.1 Publications in Conferences and Journals

Table 9 - Publications in conferences and journals in Year 2.

No	Conferences	Title	Authors	Status/Publication details
1	Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM 2014)	Technical Challenges for cognitive radio application in satellite communications [2]	UNIBO: D. Tarchi, A. Guidotti, V. Icolari, A. V. Coralli UL: S. K. Sharma, S. Chatzinotas, S. Maleki UNIS: B. Evans, P. Thompson, W. Tang NTC: J. Grotz	Oulu, Finland, Jun. 2014, In proceeding (Invited)
2	EuCNC 2014	FP7 PROJECT CoRaSat intermediate results and standardization strategy - Cognitive radio techniques in Ka band SatCom context [3]	TAS:N.Chuberre UNIS:B.Evans UNIBO: A.Vanelli-Coralli SES: J.Krause NTC: J.Gotz UL: S.Krishna Sharma	Bologna IT, May 2014
3	32nd AIAA ICSSC 2014	Cognitive Radio for Ka band satellite communications [4]	UL: Chatzinotas, Shree Krishna Sharma UNIBO: Alessandro Guidotti, Daniele Tarchi UNIS: Wuchen Tang, Barry G. Evans NTC: Joel Grotz SES: Konstantinos Liolis, Jens Krause TAS: Nicolas Chuberre	San Diego Cal, USA Aug 2014, in proceedings
4	ASMS 2014	Automatic Modulation Classification for Adaptive Power Control in Cognitive Satellite Communications [5]	UL: A. Tsakmalis, S. Chatzinotas; B. Ottersten	Livorno, IT, Sep. 2014, In proceeding
5	ASMS 2014	Implementation Issues of Cognitive Radio Techniques for Ka-band (17.7-19.7 GHz) SatComs [6]	UL: S. K. Sharma, S. Maleki, S. Chatzinotas, B. Ottersten NTC: J. Grotz	Livorno, IT, Sep. 2014, In proceeding

Table 10 – Other publications in Year 2.

No	Book Chapter	Title	Authors	Status/Publication details
1	Chapter in Elsevier Book: "Cooperative and Cognitive Satellite Systems", Editors: S. Chatzinotas, B. Ottersten, R. De Gaudenzi	"Cognitive Radio Scenarios for Satellite Communications: The CoRaSat Project" [7]	UNIBO: A. Vanelli-Coralli, A. Guidotti, D. Tarchi UL: S. Chatzinotas, S. Krishna Sharma, D. Kapetanovic UNIS: B. Evans, M. Lopez-Benitez, W. Tang SES: K. Liolis NTC: J. Grotz TAS: N. Chuberre, T. Gallet	Published 2015

5.2 Activities for Regulation and Standardization

Table 11 - Activities for regulation and standardization in Year 2.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	Presentation to Luxembourg Regulatory Authorities (ILR)	SES	November 2013, City of Luxembourg, Luxembourg	Regulator staff	UL
2	Meeting with IEEE 1900 group (Holland Oliver) in the EuCNC 2014 conference	UNIBO	June 2014, Bologna, Italy	IEEE 1900 group	ALL
3	Meeting with BIPT/INPT (Belgian regulatory authority)	NTC	September 2014, Brussels	BIPT representatives	BEL

5.3 Activities for Workshops

Table 12 - Activities for workshops in Year 2.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	EuCNC workshop on standardization and regulation for cognitive radio system organized by CRi-S.	TAS	June 2014 Bologna, Italy	Standardization & regulatory, industry, stakeholders	EU
2	Presentation of the project CORASAT to ETSI (Workshop organized by the SCN WG to raise awareness about ongoing SatCom related FP7 R&D projects)	TAS	October 2013, Oberpfaffenhoffen, Germany	Standardization & regulatory, industry, stakeholders	ALL

3	Common Workshop with ESA project FREESTONE	UNIBO and all partners	September 2014, ESA, Netherland	Standardization & regulatory, industry, stakeholders	EU

5.4 Activities for Industry dissemination

Table 13 - Activities for industry dissemination in Year 2.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	CoRaSat contribution to Panel Discussion "Terrestrial Use of Satellite Spectrum: Got Some Space to Share?", lead in conjunction with "Super Wi-Fi Summit - The Global Spectrum Sharing & TV White Space Event",	SES	January 2014 Miami, Florida, USA	Academia, Industry	ALL
2	Presentation of the CoRaSat project to ESA, invited lecture from SatNEx group	UNIBO	February 2014, Noordwijk, Netherlands	SatNEx partners plus ESA personnel, Industry, engineers	EU
3	Presentation of the CoRaSat project to the NetWorld 2020 meeting	UNIBO	June 2014, Bologna, Italy	Academia, Industry, engineers	EU

5.5 Activities for general public dissemination

Table 14 - Activities for general public dissemination in Year 2

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	Booth shared with EU projects BATS & BRESAT at the EuCNC conference	UNIBO	June 2014, Bologna, Italy	Public	EU

In year 2, we increased our output of conference papers as seen herein. This has allowed a wider dissemination of the work and now a better understanding of the project in the US and Asia from which there has been much interest.

A major success was the participation in a shared booth at the EuCNC conference in Bologna, Italy in July 2014. The other two contributing projects sharing were BATS and BRESAT. The collective title was "Next Generation Satellite Broadband systems". This was the only satellite oriented booth at the conference. During the three days of the conference we had many visitors to the booth and great interest was shown especially in the CoRaSat project. This was the first time that many of the terrestrial mobile community at the conference were aware of the work that we were doing and this exposed us to this key sector.

A second major success during the year was the acceptance of a dedicated workshop in ICC 2015. This was achieved in the face of great competition. The workshop – 'First International Workshop on "Cognitive Radios and Networks for Spectrum Coexistence of Satellite and Terrestrial Systems" (CogRaN-Sat)'will the first of its kind that focuses on satellite terrestrial frequency co-existence using cognitive techniques.

Work in the standards and regulatory areas have progressed well in ETSI and CEPT FM 44. We joined a new standards group IEEE 1900 that have just opened a work item in 'spectrum data base architectures' and are keen for us to participate in this work.

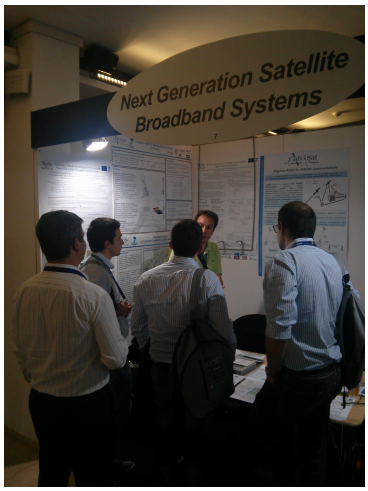

Figure 1 - The booth at the EUCNC 2014 conference including CoRaSat project description.

6 YEAR 3 ACTIVITIES

This section presents the dissemination activities and achievements of CoRaSat in the third year, which include journal and conference publications, workshops, tutorials, white papers, panel discussions, contribution to regulation and standardisation initiatives, industry-related audiences and the general public.

6.1 Publications in Conferences and Journals

Table 15 - Publications in conferences and journals in Year 3.

No	Conferences	Title	Authors	Status/Publication details
1	20th Ka conference	Frequency band sharing between satellite and terrestrial fixed links in the Ka band [8]	UniS:W.Tang, P.Thompson and B.Evans	Vietri/Salerno It Oct 2014-in proceedings
2	20th Ka band conference	Ka band satellite terrestrial coexistence: A statistical modelling approach [9]	UniS:A.Mohammed, M.Lopez-Benitez and B.Evans	Vietri/Salerno It Oct 2014-in proceedings
3	IEEE Globecom	An energy detector based radio environment mapping technique for cognitive satellite systems [10]	UNIBO:V.Icolari, D.Tarchi, A. Vanelli-Coralliand M.Vincenzi	Austin, Tx, USA December 2014
4	CROWNCOM 2015	Resource allocation for cognitive satellite uplink and fixed-service terrestrial coexistence in Ka band [11]	UL: E.Lagunas, S.Sharma, S.Maleki, S.Chatzinotas, B.Otterten. SES: J.Krause NTC:J.Gotz	Doha,Qatar April 2015
5	SPACOMM 2015	A data base approach to extending the usable Ka band spectrum for FSS satellite systems [12]	UniS: W.Tang, P.Thompson and B.Evans	Barcelona, April 2015
6	ICC 2015	Frequency sharing between satellite and terrestrial systems in Ka band: A data base approach [13]	UniS:W.Tang, P.Thompson and B.Evans	London,June 2015
7	ICC 2015	Joint carrier allocation and beamforming for cognitive SatComms in Ka band (17.3-18.1GHz) [14]	UL:S.Sharma, S.Maleki, S.Chatzinotas, B.Ottersten. SES: J.Krause NTC: J.Gotz	London, June 2015
8	ICC 2015	An interference estimation technique for satellite cognitive Radio systems [15]	UNIBO: V. .Icolari,A.Guidotti, D.Tarchi,A.Vanelli-Coralli	London, June 2015

9	ICC 2015 CogRaN –Sat workshop	Cognitive uplink FSS and FS links coexistence in Ka band: Propagation based interference analysis [16]	NTUA: .Kourogiorgas, A.Panagopoulos, SES: K.Liolis	London, June 2015
10	ICC 2015 CogRaN –Sat workshop	Analysis of interference between terrestrial and satellite systems in the band 17.7-19.7GHz [17]	UniS: P.Thompson and B.Evans	London,June 2015
11	ICC 2015 CogRaN –Sat workshop	Beam pattern allocation strategies for satellite cognitive radio systems [18]	UNIBO: V.Icolari, D.Tarchi,A.Guidiotti , A.Vanelli-Corelli	London, June 2015
12	ICC 2015 CogRaN –Sat workshop	Resource allocation for cognitive satellite communications in Ka band (17.7-19.7GHz) [19]	UL: S.Sharma, E.Lagunas, S.Catzinotas, S.Maleki, B.Ottersten. NTC: J.Gotz, SES: J.Krause,	London, June 2015
13	EuCnC 2015	Spectrum awareness and exploitation for Cognitive Radio Satellite Systems [20]	UNIBO: A.Guidiotti, V.Icolari, D.Tarchi. A.Vanelli-Corelli. UL: S.Sharma, E.Lagunas, S.Maleki, S.Chatzinotas. NTC: J.Gotz SES: J.Krause TAS: E.Corbel UniS: B.Evans, P.Thompson	Paris,June/July 2015
14	7th EAI conference WiSaT's 2015	Extending the usable Ka band spectrum for satellite communications: The CoRaSat project, [21]	UniS: B.Evans,P.Thompson UL: E.Lagunas, S.Sharma UNIBO:D.Tarchi, V.Icolari	Bradford UK, July 2015
15	7th EAI conference WiSaT's 2015	On the feasibility of interference estimation techniques in Cognitive satellite environments with impairments [22]	UNIBO:D.Tarchi,V.Icolari,A.Vanelli-Corelli,A.Guidiotti NTC:J.Gotz	Bradford, UK, July 2015
16	23rd EUSIPCO conference	Spectrum awareness techniques for 5G Satellite communications [23]	UNIBO:A.Guidiotti, D.Tarchi,V.Icolari,A.Vanelli-Corelli, G.Corazza	Nice, Fr. August/Sept 2015

17	21st Ka band conference	[Accepted]Extending the spectrum for Ka band satellite systems in the shared bands via a data base approach [24]	UniS: B.Evans, P.Thompson	Bologna, October 2015
18	21st Ka band conference	[Accepted]Impact of terrain aware interference modelling on the throughput of cognitive Ka band satellite systems [25]	UL: E.Lagunas, S.Sharma, S.Maleki, S.Chatzinotas, B.Ottersten	Bologna, October 2015
19	IEEE-VTC Fall 2015	[Accepted] Power control for satellite uplink and terrestrial fixed service co-existence in Ka band. [26]	UL: E.Lagunas, S.Sharma, S.Maleki, S.Chatzinotas, B.Ottersten	Boston,USA, Sept 2015

Table 16 - Publications in journals and journals in Year 3.

No	Journals	Title	Authors	Status/Publication details
1	IEEE Signal Processing Letters	Statistical modelling of spectrum sensing energy in multi hop cognitive radio systems [27]	UNIBO: L.Arienzo, D.Tarchi	Vol 22,No 3 pp356-360, March 2015
2	IEEE Communications Magazine	Cognitive spectrum utilization in Ka band multi beam satellite communications [28]	UL: S.Maleki, S.Chatzinotas. SES: K.liolis. UniS: B.Evans NTC: J.Gotz. UNIBO A.Vanelli-Corelli. TAS: N.Chuberre	Vol 53, No 3, pp24-29 March 2015
3	IEEE Wireless Communications Letters	Cognitive zone for broadband satellite communications in 17.3-17.7GHz [29]	UL: S.Maleki, S.Chatzinotas, B.Ottersten. SES: J.Krause, K.Liolis	Vol 4, No3, pp305-308 June 2015
4	IEEE Trans on Wireless communications	To AND orTo OR:On energy efficient distributed spectrum sensing with combined censoring and sleeping [30]	UL: S.Maleki, G.Leus, S.Chatzinotas, B.Otterten	Accepted for publication April 2015
5	IEEE Trans on Cognitive Communications and networking	Resource allocation for Cognitive satellite communications with incumbent terrestrial networks [31]	UL: E.Lagunas S.Sharma, S.Maleki, S.Chatzinotas, B.Otterten	Submitted June 2015
6	Int Journal of advances in Telecommunications	A database approach to extending the usable Ka Band spectrum for FSS satellite systems [32]	UniS: B.Evans and P.Thompson	Invited paper—submitted July 2015

6.2 Activities for Regulation and Standardization

Table 17 - Activities for regulation and standardization in Year 3.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	Presentation to Italian regulator FUB	UNIBO	January 2015	Regulator staff	IT/EU
2	Presentations and participation in IEEE 1900 Telco's	UniS	Various dates Telco	IEEE 1900 group	ALL
3	Presentations and participation in ETSI SCN	TAS	Various dates	ETSI members	EU
4	Presentation to the EU Spectrum workshop on Geolocation data base systems	UniS	March 2015 Brussels	Regulators and industry	EU
5	Presentation to the UK Spectrum Policy Forum	UniS	July 2015 London	Industry and Government	ALL

6.3 Activities for Workshops

Table 18 - Activities for workshops in Year 3.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	ICC 2015 Workshop CogRaN-Sat –Cognitive Radios and Networks for spectrum coexistence between satellite and terrestrial systems	UNIBO	June 2015, London	Academic, Industry and general	All

6.4 Activities for Industry dissemination

Table 19 - Activities for industry dissemination in Year 3.

No	Type of Activities	Main Leader	Date and Place	Audience	Countries addressed
1	Presentation of CoRaSat to open day for EU project BATS	UniS	June 2015, Guildford UK	Industry	EU

In year 3 we have continued to disseminate CoRaSat widely at various conferences. Those that applied more to the satellite community, Ka band, WiSATs and SPACOMM plus IEEE conferences Globecom, ICC, and VTC that applied to the community in general. We also presented at CROWNCOM, which focussed on the cognitive radio community and to EuCNC, which features the whole EU communications community. The paper in SPACOMM was awarded best paper status by that conference and an invitation to submit an expanded version to the journal of Advances in Telecommunication systems. This year as the work has matured we have increased our journal publications featuring IEEE journals on Wireless communications and signal processing as well as a new journal on cognitive communications and networks. We also saw the publication of our article in IEEE Communications Magazine, which reaches a worldwide audience.

We organised a special workshop on cognitive radios and networks for spectrum coexistence between satellite and terrestrial systems at ICC 2015 and this was the first time this topic had featured at an International conference. The workshop was for a full day and featured 13 papers, which had been selected from over 30 submitted as a result of the call plus two invited keynotes. Papers from China, India and Japan as well as from Europe were presented and demonstrated a wide interest.

There was a growing awareness of CoRaSat during this year, which resulted in invitations to present the work at the EU Spectrum Workshop on geolocation data base systems and the UK Spectrum Policy Forum. We added Italy to the group of regulators to whom we had made presentations. The CEPT groups FM 44 and SE 40 accepted inputs from the work and incorporated it into a consultation document to the community. We continued to update the ETSI SRDoc and support this through its publication stages as well as participating in IEEE 1900 growing work on data base standards.

7 COMPARISON OF CORASAT OUTCOMES WITH ORIGINAL TARGETS

This section summarises our outputs and compares dissemination achievements up to September 2015 with respect to the proposed plan.

In our conference publications we have exceeded target (25 to 12) by more than double and we have secured papers in a range of conferences addressing different sections of the community. Papers have appeared in the best IEEE conferences as well. For Journals we have just met our target and again the papers appeared in some of the best IEEE publications. As work is continuing with partners there will be more journal papers based on CoRaSat work to come.. In particular we are planning a special issue of the International Journal of satellite communications on the CoRaSat project which will allow us to have one single overall publication of the work done in this project. A book chapter has also been published which allows wider dissemination of the activities. We have organized or participated in 8 workshops as against a target of 3. The CogRaN-Sat workshop that we initiated and organized in ICC 2015 was of particular note a marking this area of research within the academic community and bringing together participants from around the world. We have also participated in more traditional Cognitive radio workshops and a focused workshop with the ESA project FREESTONE.

We have presented the work to 6 regulators as against a target of 4 but more widely than this we have secured a place in the CEPT activities and committees involving all the EU regulators. The CoRaSat work has been highly regarded and included in their publications. This is a major achievement as it has driven the data base activities within CEPT and persuaded them that the scheme is feasible. They are now taking this forward within their committee structure. Connected with this is the publication of a Technical report within ETSI, which has engaged the manufacturers and operators with whom we have also made awareness presentations. Thus the whole community is aware of the work and it is being taken forward.

Table 20 - Comparison of targets and current achievements.

Type of Activities	Target for Y1-Y3	Achieved in Y1-Y3
Conference	12	25
Journal	6	6
Book chapter	0	1
Workshop	3	8
Regulator	4	6
Standardisation	1	2
Industrial communities	2 Operators; 1 ESA	5 Operators; 1 ESA
General Public	Website with deliverables, reports and white papers.	Website with deliverables, reports and white papers.

8 EXPLOITATION PLANS

8.1 Scope of CoRaSat

The CoRaSat project is aimed at demonstrating the feasibility for satellite systems to use more spectrum, which is desperately needed to satisfy the future demands. Currently satellite has access to very restricted exclusive frequency bands across the spectrum but is also present in shared bands with FS, BSS and MS. In some of these bands in Europe satellite is not the incumbent and hence we need to demonstrate that these bands can be used by satellite without prejudice to the incumbents. Having reviewed all of the satellite bands it was decided to focus on Ka band where the pressure of broadband access requires considerable satellite presence. In Ka-band, only 500MHz is exclusively allocated to satellite in the uplink direction and another 500MHz in the downlink. It has been shown that especially in the downlink this is insufficient to meet demands by 2020. We thus examine the 17.3-17.7 GHz band with potential interference from BSS uplinks and demonstrate that this can be used by FSS over 98% or greater area of Europe. In the 17.7-19.7GHz band where the interference is from FS again much of the band can be used by FSS but in different portions at different locations. A data base system is shown suitable to implement this scheme. For the 27.5 to 29.5 GHz uplink there is adequate bandwidth in the HDFSS portions for BB return links for the first era of HTS satellites. Looking to the future we have examined the use of the FS components of the band by FSS using similar data base approaches as for the down link. Indications are that this would be possible although more work needs to be done to confirm this under all scenarios and conditions.

The major outcome of the work is to show that future satellites and terminals should be designed for use of these down link shared bands and database plus resource allocation or the use of SINR sensing systems should be incorporated in future systems design.

8.2 Stakeholders interest in CoRaSat

The satellite operator (SES) main interest in this project is to acquire knowledge on the investigated CR technologies through which the exploitation of extra shared frequency bands spectrum will become available to meet the future capacity demand. In particular, the concept for shared band investigation is that the considered frequency bands have shared allocation since many years, and are actually shared today (*e.g.* 18.3-18.8 GHz on ASTRA 1L is used for satellite news gathering, downlink to TV studios). For SES, the CoRaSat concept is novel as it will allow the exploitation of shared frequency bands to be used by mass deployed satellite terminals (HDFSS) without prior individual frequency coordination.

The satellite system manufacturer (TAS) in the project has a stake in the design of end to end satellite communication systems and manufacture of the 2020 satellites using the new bands and the equipment development therein. Satellites that incorporate the extended bands are the target for future design and manufacture.

The terminal manufacturer (NTC) similarly has a stake in the future design of terminals to incorporate the new bands and how the data base technology will integrate with their terminals and gateways. Significant equipment development is foreseen in this area and this has been started with the CoRaSat demonstrator.

The three Universities (UNIBO, UNIS, UL) involved in the project have a research interest in exploiting their IPR with the partners as well as in using it as background to secure new research

work. In addition their interest is in publishing quality papers and flowing the knowledge to future generations of researchers and students.

8.3 Exploitable Knowledge and Plans

In the following each of the partners expands on their exploitation plans.

8.3.1 University of Bologna

8.3.1.1 Mission and Vision

The research group of the University of Bologna, identified as Digicomm Research has a long lasting experience in design and assessment of Wireless and Satellite Communication techniques, architecture, and systems developed and demonstrated in many research activities most of which founded by the European Space Agency and the European Commission. Digicomm Research participation to CoRaSat aims at enlarging and consolidating the group knowledge portfolio that is exploited for the institutional objectives, *i.e.*:

- undergraduate teaching;
- graduate teaching;
- PhD high education training;
- knowledge transfer;
- research activity;
- spin-off creations (where possible).

It is worthwhile noting that exploitation of research results produced by funded EC/ESA projects allows the Digicomm Research group to provide high level background to PhDs that are now employed in several SatCom related initiatives (*e.g.*, ESA, GSA, Qualcomm, British Telecom, etc.).

8.3.1.2 Exploitable Knowledge

Exploitable knowledge developed by UNIBO in the framework of the CoRaSat project is summarized in Table 21.

Table 21 - Exploitable knowledge for UNIBO.

	Exploitable knowledge/products	**Sector of application**	**Timeframe**	**Patents or other IPR protection**
1	Spectrum sensing techniques	Wireless and SatCom	Theory/Software available	Know how
2	Interference estimation	Wireless and SatCom	Theory/Software available	Know how
3	System behaviour	Wireless and SatCom	Theory available	Know how

8.3.1.3 Opportunities

UNIBO aims at extending the 'know how' developed for spectrum sensing and interference estimation, so as to solve any technical challenge that may be identified. Moreover, the interference estimation know how provides input to resource allocation algorithm, in which UNIBO sees opportunities for valuable future research activities and funded projects. Interference estimation techniques can also be used to provide inputs to those databases for which information cannot be provided by national regulators, due to confidentiality aspects. Thus, synergies with regulatory bodies can also be exploited, as well as synergies with ESA projects.

8.3.1.4 Progress and Outcomes

The 'know how' for the developed techniques is now stable. UNIBO plans to extend this know how so as to make the overall algorithm as robust as possible to any eventual technical challenge. Moreover, resource allocation algorithm exploiting outputs from the interference estimation module will be analyzed. UNIBO submitted several papers related to spectrum sensing and interference estimation, and has planned to publish more conference papers and at least one major journal paper during the next year.

8.3.2 Thales Alenia Space

8.3.2.1 Mission and Vision

Thales Alenia Space, is a key European player in space telecommunications, navigation, Earth observation, exploration and orbital infrastructures. In particular, it is one of the world's leading manufacturers of communications satellites, platforms and payloads, which account for 50% of its business. The company offers a complete range of solutions, from high-performance components to turnkey systems.

Thales Alenia Space's High throughput satellite solutions draw on its long and extensive heritage in multibeam Ka-band technologies and products, starting in 1991 and ranging from complete systems (Syracuse, Yahsat, O3B, Athena-Fidus, Sicral, SGDC-1, etc.) to the supply of individual components and subassemblies.

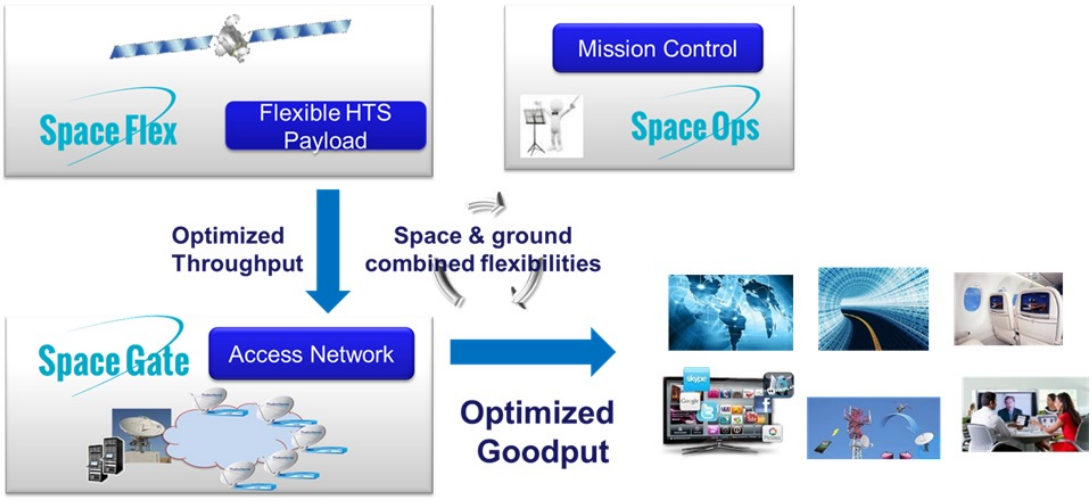

Figure 2 - TAS product/technology developments on HTS satellite systems.

TAS is engaged in the development of the necessary technologies at both space and ground segments to develop future high throughput geostationary satellite systems which are mostly operating in the Ka band intended to provide very high speed broadband access services to professional and consumers in low density populated areas (rural and sub-urban areas in Europe and other region of the world).

In order to decrease cost / Mbps transmitted and meet the expected traffic growth, additional spectrum are necessary to further increase the satellite throughput. Typically, Q/V band or possibly optical bands are considered for the gateway link while access to the Ka band spectrum chunk allocation shared with Fixed Services is necessary for the service link with the terminals.

By taking part in CoRaSat, TAS has contributed with the project partners to demonstrate a safe coexistence of satellite services with terrestrial microwave links in the shared portion of the Ka band spectrum chunk and therefore make possible the use of extended Ka band spectrum chunk for very high throughput satellite networks.

8.3.2.2 Exploitable Knowledge

Exploitable knowledge developed by TAS in the framework of the CoRaSat project is summarized in Table 22.

Table 22 - Exploitable knowledge for TAS.

	Exploitable knowledge/products	**Sector of application**	**Timeframe**	**Patents or other IPR protection**
1	Know-how in the benefits and constraints CR technologies enabling satellite design exploiting the shared frequency bands spectrum in Ka-band.	SatCom Solution design and manufacturing	At CoRaSat project completion	Know-how
2	CR techniques (Dynamic Channel Allocation)	Feature for Satellite Broadband access network solution	At CoRaSat project completion	Know how
3	Regulatory framework for Cognitive Radio techniques	Support to High Throughput Satellite service set-up	At CoRaSat project completion	Know how

8.3.2.3 Opportunities

Access to extra spectrum resources (17.3-17.7 GHz and 17.7-19.7 GHz in downlink as well as 27.5-29.5 GHz in uplink) enable to increase the capacity of the next generation of high throughput satellite systems and to reduce the cost of Mbps via satellite. This will increase the market potential of satellite broadband currently restricted to isolated areas.

Hence CR features will provide a key market differentiator for next generation satellite broadband solutions.

Given that no road block for the CR features deployment/operation have been identified, TAS is already designing its HTS satellite (SpaceFlex) so that they can operate in both the exclusive and non-exclusive spectrum allocations to FSS/MSS in Ka band.

The challenge remains to develop low cost terminals agile in all the spectrum and implementing sensing capabilities to assess/report its interference context.

TAS has developed a simulation tool partly based on the know-how acquired during the project which aims at assessing the useful capacity that can be achieved using both the exclusive and non-exclusive spectrum allocations. This tool is used to promote its satellite system towards customers during the bids but also to optimise the nominal frequency plan of the system. It however requires access to database on FS and BSS stations deployment that can be provided by regulatory administration. The more information are available, the best spectrum usage can be made in the non-exclusive allocation.

Furthermore, the CR features are also envisaged to be implemented in Non Geostationary Synchronous Orbit (NGSO) systems operating in the Ka band exclusive and non-exclusive spectrum allocations to FSS/MSS.

8.3.2.4 Progress and Outcomes

The project has managed to demonstrate at regulatory level the safe coexistence of "Cognitive" Fixed satellite services with microwave links and legacy Broadcast Satellite services in Ka band shared spectrum without needing any modifications to the existing regulatory framework.

It is however recommended to encourage the provision by administrations of databases containing information about FS and BSS deployments to maximise the spectrum usage by satellite systems. Also, the continued access of the Ka band for satellite services shall be ensured on the long term, taking benefit of the huge investment committed by the satellite industry in R&D and actual deployments. This long-run investment in the Ka band shall not be threatened by potential uses by the terrestrial mobile industry.

This was made possible thanks to a tight cooperation in CoRaSat between the partners each having a complementary role:

SES: The satellite operator defining the use cases and services

TAS: The system prime defining the system reference scenario and architecture

NTC: The SatCom vendor implementing and testing the CR techniques

UNIBO, UNIS and UL: The research centres each addressing the design/assessment of CR for the three frequency scenarios selected

8.3.3 SES

8.3.3.1 Mission and Vision

SES (www.ses.com) is a world-leading satellite operator who provides satellite communications services to broadcasters, content and internet service providers, mobile and fixed network operators, and business and governmental organisations worldwide. SES owns and operates a fleet of over 50 GEO satellites that are complemented by a network of teleports and offices located around the globe. This far-reaching infrastructure enables SES customers to reach 99% of the world's population and places SES at the heart of the global communications chain. SES also holds a strategic participation in O3b Networks (www.o3bnetworks.com) that is building a new fibre-quality, satellite-based, global internet backbone for telecommunications operators and internet service providers in emerging markets, based on a Ka-band MEO High Throughput Satellite (HTS) constellation.

SES has one of the two largest commercial spacecraft fleets. A first step in Ka-band was taken with the ASTRA 1H, ASTRA 1K, ASTRA 1L, Sirius 4 and ASTRA 3B mono-beam satellites, and a second step was taken successively with the AMC-15 and AMC-16 multi-beam satellites. A third significant step in Ka-band for Ka-Band Broadband Services over Europe has been the three ASTRA-2 replacement satellites (*i.e.*, ASTRA 2F, ASTRA 2E, and ASTRA 2G), which each one includes a steerable Ka-band beam that can be flexibly pointed over Europe, and ASTRA 5B satellite, which includes a jointly steerable twin-beam Ka-band payload. This capacity has been deployed since 2014 according to the SES fleet replacement plan with the objective to complement the current pan-European Ku-band broadband coverage with incremental Ka-band capacity over selected areas.

In terms of broadband services, SES ASTRA's "Broadband Interactive System" (BBI) service was the first commercial broadband satellite service available across CEPT countries using Ka-band (as well as Ku-band), whose commercial availability started in 2001. In CEPT countries, the first Ka band satellite broadband service was implemented by ASTRA 1H and ASTRA 1L which include transponder capacity in Ka-band for return path transmissions from the user to the service provider via the satellite. The follow-up of SES ASTRA's BBI service is ASTRAConnect (formerly referred to as "ASTRA2Connect"), which aims at delivering services to a high number of customers, including individual users. ASTRAConnect is broadband Internet via satellite from SES TechCom Services (http://www.astraconnect.com/), named after the fleet of ASTRA satellites used to provide high speed broadband connections. ASTRAConnect originally operated in Ku-band only and currently operates also in Ka-band.

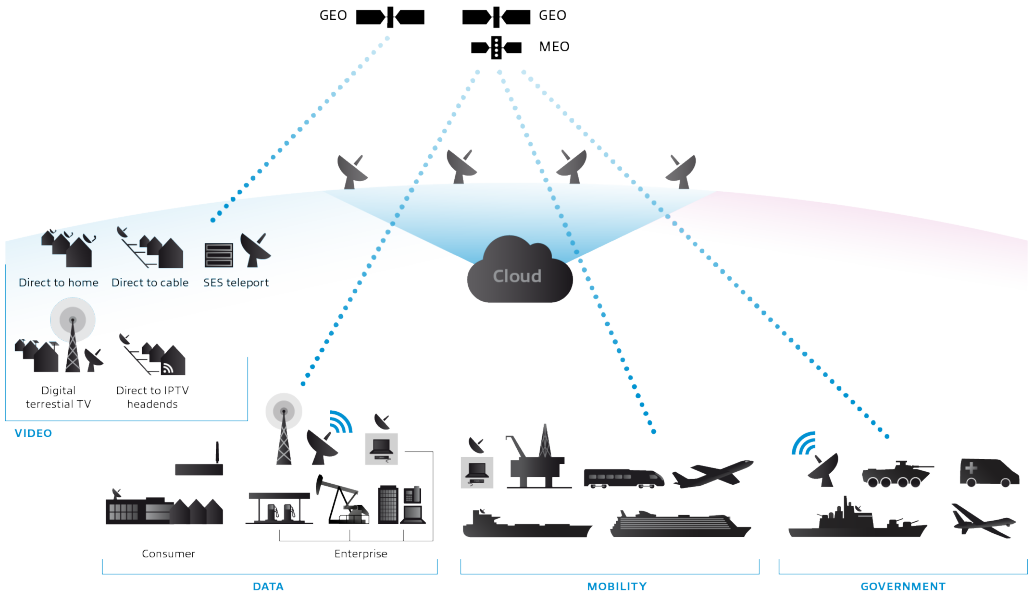

Figure 3 - SES Ecosystem: Providing connectivity with integrated offerings of GEO and MEO satellites.

In addition to GEO satellites, through its strategic participation to O3b Networks (www.o3bnetworks.com) which owns and operates a Ka-band MEO HTS constellation of (currently) 12 satellites, SES has built a solid ecosystem capable of providing connectivity with integrated offerings of GEO and MEO satellites (see Figure 3) O3b Networks is an innovative satellite network, which combines the reach of satellite with the speed of fiber, providing around 70% of the world's population with fiber quality internet connectivity. The O3b system is based on a Ka-band MEO satellite constellation (on a single 8062 km orbit), with high link trunking capacity (theoretical speed

up to 1.2Gbps per beam). The O3b service is already operational. The main targeted communication services are mobile backhauling and IP trunking (telcos sector), which are further complemented by maritime and energy services (enterprise sector) as well as governmental services.

Regarding future investments, SES has already future business plans for multi-spot beam payload HTS satellites. SES fleet investment to serve future-proof networks is illustrated in Figure 4. In particular, SES-12, SES-14 and SES-15 refer to new HTS multi-spot beam satellites of SES to be launched in the near future:

- SES-12 is a new GEO hybrid communications satellite to serve the fast growing DTH, Data, Mobility and Government markets in Asia. It is scheduled for launch in 2017 and will operate at 95^{o} East, providing incremental as well as replacement capacity with excellent view angles across the Asia-Pacific region. SES-12 will replace NSS-6 and will be co-located with SES-8. SES-12 satellite is fully electric (SES-12 and SES-14 have the same platform). The payload of the hybrid SES-12 satellite consists of two distinct but complementary missions: i) A mission with traditional Ku-band wide beam coverage, and ii) A second mission with a high-powered Ku-band multi-spot beam HTS payload consisting of 70 Ku-band spot beams and 11 Ka-band spot beams delivering over 14 GHz for VSAT, Enterprise, Mobility and Government applications. The latter mission also includes a Digital Transparent Processor (DTP), which provides increased payload flexibility in order to provide customized bandwidth solutions to SES customers.
- SES-14 is a new GEO satellite to capture growth opportunities in dynamic markets, buoyant business segments and growing video neighborhoods across the Americas and the North Atlantic region. It is scheduled for launch in 2017 and will operate at 47.5/48^{o} West, where it will replace SES's satellite NSS-806 and add new capacity. SES-14 is a hybrid satellite with C- and Ku-band wide beam coverage, as well as Ku-band multi-spot beam HTS and Ka-band coverage across the Americas and the North Atlantic region. The satellite will fully rely on electric propulsion and will be equipped with an electric plasma propulsion system for orbit raising and in-orbit manoeuvres. The electric propulsion system delivers significant reduction in the weight of the satellite, enabling larger payloads to be carried. The new spacecraft will also feature a DTP, increasing the payload flexibility to provide customized bandwidth solutions to SES's customers. SES-14's multi-spot Ku- and Ka-band beams will bring additional, high throughput capacity and are ideal for traffic-intensive data applications such as mobile backhaul, maritime and aeronautical services.
- SES-15 is a new GEO satellite to provide growth capacity in North America and capture business potential in vibrant market segments. It is scheduled for launch in 2017 and will open up a new orbital location to serve North America. SES-15 will carry a hybrid payload, with additional Ku-band wide beams as well as Ku-band multi-spot beam HTS and Ka-band capability. The satellite will be equipped with an electric propulsion system for orbit raising and in-orbit manoeuvres. Alongside the newly procured SES-14 satellite, SES-15 will solidify SES's positioning in the aeronautical mobility and government markets, providing fresh capacity and coverage over major airline routes across the continent. SES-15 will enable SES to serve its leading aeronautical customers and serve other traffic intensive data applications such as government, VSAT networks and maritime.

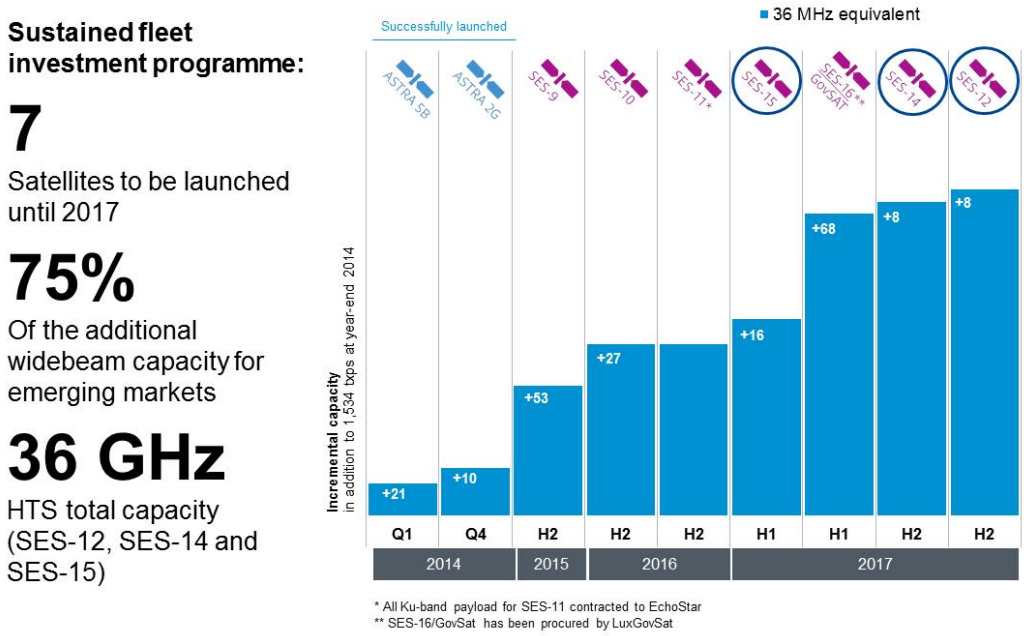

Figure 4 - SES fleet investment to serve future-proof networks.

At this point, it is important to note that none of the SES satellites so far (incl. existing fleet and announced future fleet investment) includes a new generation GEO Ka-band multi-spot beam HTS payload, which is the baseline architecture considered in CoRaSat. Being a world-leading satellite operator, SES is committed to providing state-of-the-art satellite communications services to its customers. Participation in innovation projects like CoRaSat is essential and differentiates SES from its competitors since it allows:

- To remain at the forefront and validate state-of-the-art technologies like Cognitive Radio (CR),
- To understand how and where to apply such innovative technologies and solutions more effectively,
- To understand the risks, threats and challenges associated to these technologies, and
- To acquire the necessary skills and know-how allowing so to proceed to potential future investments as necessary.

Thus, SES' main interest in the CoRaSat project is to acquire knowledge on the investigated CR technologies through which the exploitation of extra shared frequency bands spectrum will become available to meet the future capacity demand. In particular, the concept for the proposed shared band investigation in Ka-band is that the considered frequency bands have shared allocation since many years, and are actually shared today (e.g., 18.3-18.8 GHz on Astra 1L is used for satellite news gathering, downlink to TV studios). For SES, the CoRaSat concept is novel as it will allow the exploitation of shared frequency bands to be used by mass deployed satellite terminals (HDFSS) without prior individual frequency coordination, in conjunction with GEO Ka-band multi-spot beam HTS satellites.

8.3.3.2 Exploitable Knowledge

Exploitable knowledge developed by SES in the framework of the CoRaSat project is summarized in Table 23.

Table 23 - Exploitable knowledge for SES.

	Exploitable knowledge/ products	Sector of application	Timeframe	Patents or other IPR protection
1	Know-how in CR technologies facilitating satellite use of extra shared frequency bands spectrum in Ka-band.	Broadband SatCom Services Provision	By end of CoRaSat project	N/A (know-how)
2	Know-how in CR technologies facilitating other applications beyond Spectrum Sharing and also in conjunction with 5G, such as Spectrum Monitoring and Interference Management.	SatCom Services Provision	By end of CoRaSat project	N/A (know-how)
3	Understanding of the risks, threats and challenges associated to the use of CR technologies for spectrum sharing scenarios in the satellite business.	SatCom Services Provision	By end of CoRaSat project	N/A (know-how)
4	Mass deployment of FSS satellite terminals in shared frequency bands without prior individual frequency coordination in Ka-band and in conjunction with GEO Ka-band multi-spot beam HTS satellites.	Broadband SatCom Services Provision	Short-to-Medium Term after CoRaSat project completion (depending upon stakeholders' product roadmaps)	N/A (know-how)

8.3.3.3 Opportunities

For the exploitation of CoRaSat project results, SES intends to use them in multiple ways:

- **Partnership with Key Stakeholders:** SES expects that the cost effective CR technologies will be offered commercially in reasonable short-to-medium timeframe by the industry stakeholders and suppliers. The implementation of these CR technologies would provide SES the substantial benefit to be able to access extra shared frequency bands spectrum in Ka-band, as such being in a position to provide further improved or even new broadband services. To this end, the collaboration with CoRaSat industrial partners – being strategic vendors, i.e., Newtec: terminal manufacturer, Thales Alenia Space: satellite manufacturer – provides already a good opportunity towards this direction.
- **Regulatory Framework:** SES expects that the CoRaSat project results will provide the foundation of the relevant rules, procedures and provisions for CR in the regulatory environment at EU and national levels in order to have an efficient environment in which all stakeholders can exploit related benefits with overall less effort than before. To this end, the regulatory gap analysis conducted by SES in CoRaSat WP2 provides already another good opportunity in this respect (see CoRaSat Deliverable D2.5 "Regulatory and Standardisation

Framework – Detailed Report"). Moreover, the CoRaSat dissemination activities conducted towards Regulatory Authorities and, in general, Policy Makers in the context of Ka-band scenarios (e.g., ESA, CEPT, FM44, ILR, etc) provides already a good opportunity towards this direction. In particular, based on CoRaSat support, sharing studies have been undertaken in CEPT SE40 and are reflected in the ECC Report 232 "Compatibility between FSS uncoordinated receive Earth Stations and the FS in the band 17.7-19.7 GHz". This report investigates the availability of spectrum for FSS earth stations in areas with FS deployment. Furthermore, the ECC is expected to adopt by early 2016 the following deliverables:

  - ECC Report 241: Enhanced access to spectrum for FSS uncoordinated Earth Stations in the 17.7-19.7 GHz band. This report investigates technical and regulatory measures to enhance the conditions of operation for uncoordinated FSS earth stations in the 17.7-19.7 GHz band, including the use of FS assignment information.
  - Revised ERC/DEC(00)07: The shared use of the band 17.7-19.7 GHz by the fixed service and Earth stations of the fixed-satellite service (space-to-Earth).

- **Standardization Framework:** In the standardization domain, the starting point for ETSI work on a standard about the use of Ka-band spectrum sharing has already been established through CoRaSat. To this aim, the CoRaSat project produced a Technical Report for approval at the Technical Committee on Satellite Earth Stations and Systems (TC-SES) within ETSI. The technical report was submitted to TC-SES as well as to the Technical Committee on Electromagnetic Compatibility and Radio Spectrum Matters (TC-ERM) and subsequently converted in a System Reference Document (SRDoc) intended for liaison with CEPT FM44. The SRDoc was successfully published by ETSI as TR 103-263 v1.1.1 "Cognitive Radio Techniques operating in Ka-band" in July 2014, and CoRaSat is now working its way through updates which involve the satellite operators and equipment manufacturers. This constitutes an important opportunity for SES towards multi-spot beam HTS satellites with extended Ka-band.
- **New Bids and Contracts:** Knowledge gained from conducted R&D work within CoRaSat is intellectual property that SES has already exploited as background knowledge in bidding for and acquiring additional innovation related contracts. As an illustration, CoRaSat allowed SES to bid and acquire the following R&D projects funded by FNR (Fonds National de la Recherche Luxembourg, http://www.fnr.lu/):
  - FNR CORE "SATSENT" (SATellite SEnsor NeTworks for spectrum monitoring, http://wwwen.uni.lu/snt/research/research_projects2/satsent_satellite_sensor_networks_for_spectrum_monitoring)
  - FNR CORE "SEMIGOD" (Spectrum Management and Interference Mitigation in Cognitive Radio Satellite Networks, http://wwwen.uni.lu/snt/research/research_projects2/semigod_spectrum_management_and_interference_mitigation_in_cognitive_radio_satellite_networks)
  - Other H2020 R&D Project Proposals related to 5G and Ka-band HTS satellites.

8.3.3.4 Progress and Outcomes

WP2 Outcomes (led by SES): SES-led WP2 activities were successfully completed in project Y1. In this regard, significant know-how in CR technologies for spectrum sharing has been achieved, especially from business/market, regulatory, standardization and technological perspectives. Market

and Service Requirements for Proof-of-Concept implementation but also with view to future commercial roll-out phase have been well defined (see CoRaSat Deliverables D2.1 and D2.4). Moreover, the risks, threats and challenges imposed to the satellite business and associated to the use of CR technologies for spectrum sharing scenarios, especially in the regulatory domain, have been well understood and the importance to protect satellite industry interests accordingly has been raised (see CoRaSat Deliverables D2.2 and D2.5). In particular, associated barriers and risks have been well understood and documented in the CoRaSat Deliverable D2.5 "Regulatory and Standardisation Framework – Detailed Report", and can be summarized as follows:

- Database security (Confidentiality, Integrity, Availability)
- CR equipment certification
- Spectrum trading
- Complex international regulatory framework
- Different maturity level in developed vs. developing countries
- High density deployment of FSS and FS
- Accuracy and availability of incumbent links' deployment data
- Additional Costs imposed due to CR introduction

WP5 Outcomes: SES has also been active in WP5 activities. In this regard, being an ETSI Member, SES has supported ETSI SRDoc standardization "Cognitive radio techniques for Satellite Communications operating in Ka band" and contributed to the ETSI SRDoc documentation as well as to the related ETSI meetings and discussions held therein. SES has also actively supported dissemination of CoRaSat project results towards industrial (e.g., O3b Networks, Avanti) and technological audiences (e.g., IEEE journal and conference papers, Book Chapter, etc) but also towards regulatory authorities and policy makers (e.g., ESA, CEPT, FM44, ILR, etc).

WP3/WP4 Outcomes: SES has also contributed to WP3 and WP4 activities. In this regard, SES has followed the discussions on CR technologies under investigation and provided feedback from the satellite operator's perspective, as necessary. Especially, the completion of WP4 HW prototyping and in-lab validation activities has been an important milestone for SES which helped to further demonstrate the potential benefits of CR technologies to the satellite industry in a more realistic environment.

8.3.3.5 Post-CoRaSat Plans

As mentioned earlier, it is important to note that none of the SES satellites so far (incl. existing fleet and announced future fleet investment) includes a new generation GEO Ka-band multi-spot beam HTS payload, which is the baseline architecture considered in CoRaSat. As such, based on gained know-how, CoRaSat could represent a step forward for SES towards new future multi-spot beam HTS satellites with extended Ka-band frequency spectrum through the adoption of CR technology.

Frequency Plan

For such a future potential GEO multi-spot beam HTS satellite with extended Ka-band spectrum, and building upon CoRaSat work, SES has come up with a tentative frequency plan which is depicted in Figure 5 and also summarized in Table 24 below. The frequency plan assumes a GEO Ka-band FSS two-way broadband satellite system, with a multi-star network over a multi-spot beam HTS payload with extended Ka-band frequency spectrum and a 4-color frequency reuse scheme. All frequencies are

allocated on the two polarizations and the usage of circular polarization (i.e., RCHP and LCHP) is assumed in the FSS system.

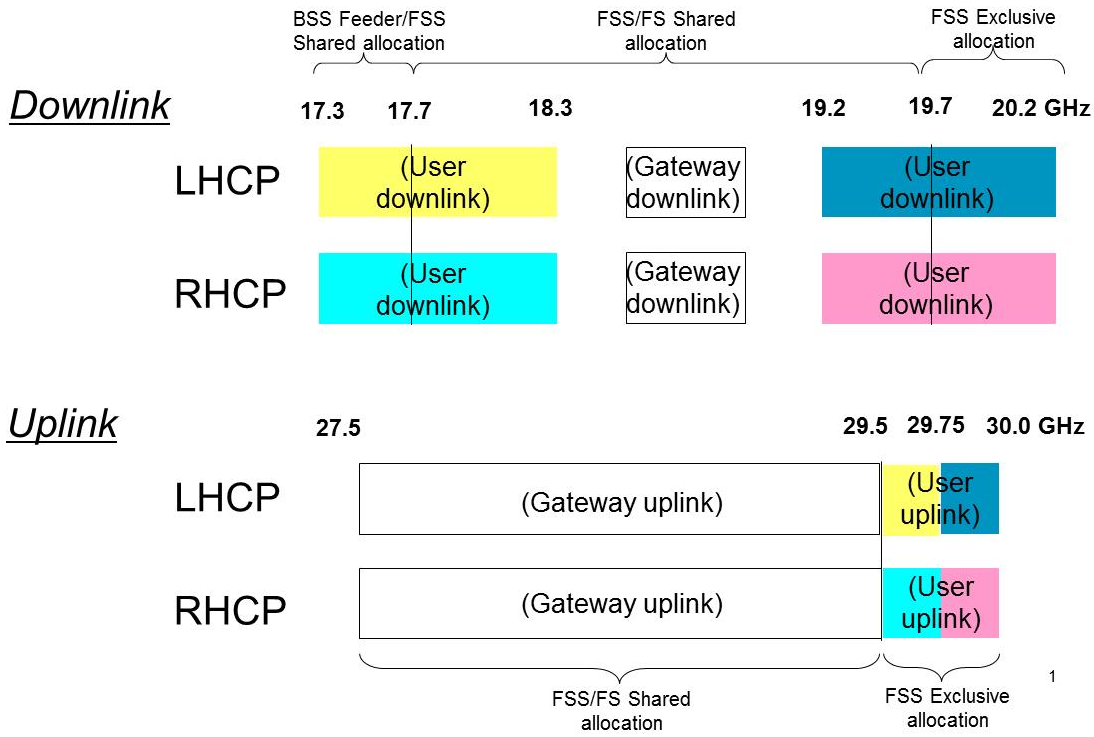

Figure 5 - Tentative Frequency Plan of future GEO multi-spot beam HTS satellite with extended Ka-band.

Table 24 - Frequency Plan Summary.

Link	Beam Frequency Allocations	
User Downlink (BW=2 GHz)	17.3 – 17.7 GHz satellite exclusive band 17.7 – 18.3 GHz shared band	19.2 – 19.7 GHz shared band 19.7 – 20.2 GHz satellite exclusive band
User Uplink (BW=500 MHz)	29.5– 29.75 GHz satellite exclusive band	29.75– 30.0 GHz satellite exclusive band
Gateway Downlink (BW=500 MHz)	500 MHz part within 18.3 – 19.2 GHz shared band	
Gateway Uplink (BW=2 GHz)	27.5 – 29.5 GHz shared band	

Note that this frequency plan is different from the two baseline ones considered in the CoRaSat project (see CoRaSat Deliverable D3.1). In particular, it assumes that both the User links and the Gateway links are located in Ka-band. In this way, there is no need to employ higher frequency bands, such as Q/V, W or even Optical bands, for the Gateway links where there is currently no flight-proven technology available. This makes the proposed frequency plan applicable in a shorter timeframe. It also results in a more cost-efficient solution for the satellite operator (SES).

In addition, the proposed frequency plan considers the following:

- The 2 GHz BW of User DL assumes the utilization of 500 MHz of FSS Exclusive allocation (*i.e.*, 19.7 – 20.2 GHz) and 400 MHz of BSS Feeder allocation (i.e., 17.3 – 17.7 GHz). The rest of 1.1 GHz BW (*i.e.*, 2 GHz – (500+400 MHz)) for the User DL is Open. In the current frequency plan, it is assumed that the 17.7 – 18.3 GHz and 19.2 – 19.7 GHz parts at the edges of the FSS/FS

shared frequency band complement the User DL (in total, 2 GHz). This in turn has an impact on the Start/End Frequency of the GW DL part, which are TBD and should refer to 500 MHz part within the 18.3 – 19.2 GHz FSS/FS shared band.

- This in turn means that (part of) the Teledesic bands (28.6 – 29.1 GHz UL and 18.8 – 19.3 GHz DL) will be employed for the GW UL and GW DL, respectively, of such a potential GEO satellite system. To this end, given that SES holds a strategic participation in Ka-band MEO HTS based O3b Networks, there will be a special need for GSO-NGSO coordination with O3b Networks particularly for the use of the Teledesic bands.

New Satellite Procurement Project

For the potential procurement of such a future potential GEO multi-spot beam HTS satellite with extended Ka-band spectrum, SES would employ standard commercial best-practices used for the procurement of commercial telecom satellites. To this end, the Work Package (WP) structure of such New Satellite Procurement Project can be summarized as follows:

WP1 Project Coordination

WP2 Sales / Business Development

WP3 Service/Product requirements

WP4 Market Demand

WP5 Frequency Resources

WP6 Commercial Requirement

WP7 System Architecture and Satellite Design

WP8 Ground Segment

WP9 Business Case and Financial Analysis

WP10 Satellite Procurement – Payload

WP11 Satellite Procurement – Contractual &Commercial

Figure 6 below illustrates the work logic and simplified view of the activity flow above, taking into account CoRaSat project results as well.

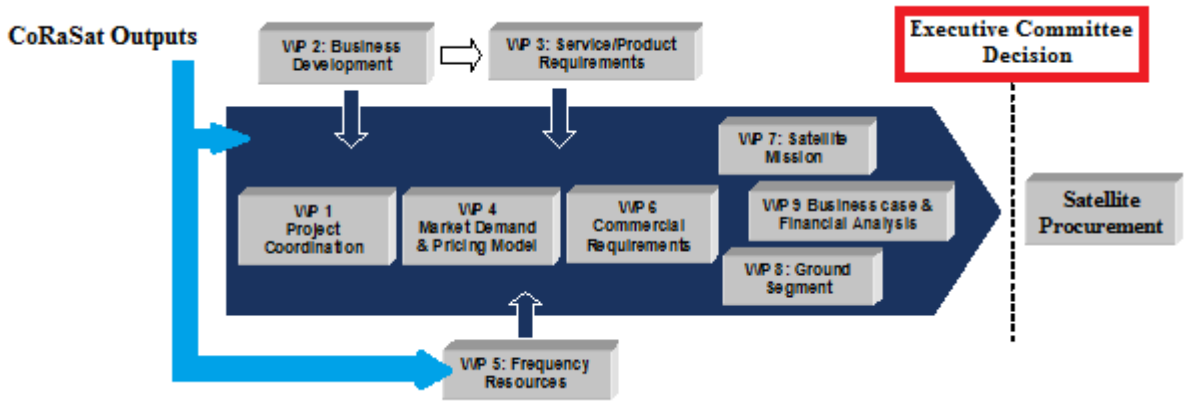

Figure 6 - Work Logic for Potential New Satellite Procurement Project.

Note that, in line with one of the CoRaSat Y1 review recommendations suggesting a quantitative financial assessment of the business potential for the different scenarios as well as in line with CoRaSat response provided, such financial assessment is indeed one of the tasks to be conducted as part of the potential follow-up procurement project WP9 "Business Case and Financial Analysis". In fact, WP9 Tasks include:

- Elaborate a financial plan for the lifetime of the satellite.
- Elaborate a business case for the satellite.
- Elaborate a financial risk assessment.

In fact, these WP9 tasks are essential tasks for such significant investment, for which it is a best practice approach for satellite operators like SES to put in place only at a later stage once the technological gains are clearer.

Risks

Regarding major risks for the way forward, these can be summarized as follows:

- WRC-15 is likely to propose an agenda item for WRC-19 for mobile broadband (IMT) spectrum above 6GHz. Satellite sector should aim to guide those discussions to spectrum above 31 GHz. Currently, terrestrial mobile vendors and operators want to keep all options open above 6 GHz and some of them have a particular interest in satellite Ka-band.
- Given that (part of) the Teledesic bands will be employed by such a future potential Ka-band GEO HTS satellite system as well as given the fact that SES holds a strategic participation in O3b Networks being based on Ka-band MEO HTS satellites (see SES Ecosystem in Figure 3), special attention shall be paid to the GSO-NGSO coordination with O3b Networks as well as with other future announced NGSO initiatives particularly for the use of the Teledesic bands.
- Given the expected increase in demand for broadband access and the resulting proliferation of Ka-band HTS satellites in the GEO arc expected in the near future, the orbital slot for such a Ka-band GEO HTS satellite needs to well-coordinated with other Ka-band GEO HTS satellites in order to avoid adjacent satellite interferences.
- Other risks, threats and challenges imposed to the satellite business and associated to the use of CR technologies for spectrum sharing, especially in the regulatory domain, as elaborated in CoRaSat Deliverable D2.5 "Regulatory and Standardisation Framework – Detailed Report" and outlined above.

For the approval and launching of such a potential New Satellite Procurement Project addressing a new generation GEO multi-spot beam HTS satellite with extended Ka-band spectrum, the impact of such major risks must be minimized prior to approaching the SES Executive Committee and Board of Directors.

8.3.4 University of Luxembourg

8.3.4.1 Mission and Vision

The Interdisciplinary Centre for Security, Reliability and Trust (SnT), launched by the University of Luxembourg (UL), targets research and PhD education in Security, Reliability and Trust and provides a platform for interaction and collaboration between university researchers and external partners (industry/institutes/government). The overall aim of SnT is to become an internationally leading

research facility that together with external partners establishes Luxembourg as a European centre of excellence and innovation for secure, reliable, and trustworthy ICT (Information and Communication Technologies) systems and services. To create an impact, an interdisciplinary research approach is essential, taking not only technical aspects into account but also addressing business/organizational, human/user, and legal/regulatory issues. To achieve this goal, recently a Technology Transfer Office (TTO) is established in SnT in order to facilitate the promising research ideas to go all the way from proof of concept to the market.

8.3.4.2 Exploitable Knowledge

Exploitable knowledge developed by UL in the framework of the CoRaSat project is summarized in Table 25.

Table 25 - Exploitable knowledge for UL.

	Exploitable knowledge/products	**Sector of application**	**Timeframe**	**Patents or other IPR protection**
1	Carrier Allocation Module	Satellite operators	Software available.	Know how
2	Joint Carrier and Power Allocation Module	Satellite users and operators	Software available	Know how
3	Terminal beamforming	satellite users and operators	Software available	Know how
4	Terrain aware interference modelling module	Satellite users and operators	Software available	Know how
5	Full-fledged resource allocation module	Industry, regulations and research	Algorithms and Software available	Know how
6	Achievable throughputs	Regulation and research	Results are available	Published in part

8.3.4.3 Opportunities

The CoRaSat project results will be exploited by UL towards the following directions: academic dissemination, research expertise, knowledge transfer, patenting. More specifically, UL as an academic institution will publish the results in highly-esteemed journals and conferences with the purpose of improving its academic merit and promoting this research area in the international academic community. Furthermore, the acquired experience through CoRaSat will improve the research competencies within UL and provide opportunities for PhD and MSc student training. In addition, UL aims at transferring knowledge with the help of TTO through its partner program and creating synergies with its industrial partners (*e.g.*, SES with which SnT has a long-term strategic partnership). Finally, possible architectures and algorithms that can be commercially exploited will be protected through patenting.

8.3.4.4 Progress and Outcomes

We have developed the required software, i.e. the CoRaSat simulator to allocate the carriers/power to the users optimally, and the initial results are very promising (>600% improvement in throughput per beam for downlink scenarios, as well as around 400% for the uplink Scenario). The results are published in part in conference papers, and we submitted a journal paper. The knowledge achieved from this activity was used in bidding for several successful ESA projects, as well as an H2020 European project, SANSA which has been successfully accepted and is running at the moment The CoRaSat simulator is being included in a generalized cognitive SATCOM simulator which not only addresses the CoRaSat scenario but can be applied to other scenarios as well such as shared terrestrial and satellite backhauling, which is considered in H2020 project SANSA.

8.3.5 Newtec

8.3.5.1 Mission and Vision

Among other product developments, Newtec intends to develop its future products in line with the requirements of the two-way satellite broadband access market both for consumers and for professional applications.

In this respect the input from CORASAT is an important element to identify and define key technical requirements that need to be addressed in the next generation of two-way satellite broadband access systems, especially high throughput satellite access systems, which exploit shared frequency bands. The scenarios considered within the CORASAT project are of high importance in this context as these are the result of a diligent consultation work involving operators, satellite manufacturers as well as universities and input from regulatory authorities.

8.3.5.2 Exploitable Knowledge

The current developments related to CORASAT are exploitable on system level in the context of techniques required for joint management and control of a system that operates in a secondary frequency band, with an incumbent user present. In addition the requirements that drive the user terminal are also addressed and defined in the context of CORASAT. The requirement derived from the CORASAT project from the defined scenarios and considering the defined use cases and key performance indicators (KPI) as defined on the project. This requirements basis is essential to define the developments for the platform in details.

A detailed understanding of the system and terminal requirements is an essential basis for the development work, including:

- The definition of the RF front-end and antenna specifications are an important for the requirements definition of the next generation of terminals.
- The system level requirements definition of what needs to be implemented to manage and operate a satellite system that exploits frequency bands that are shared with other systems
- Implemented and tested technology features are the following:

  Dynamic Capacity Allocation (DCA) functionality in the forward and return link; This feature includes the system capability of changing of the terminal forward and return link assignment to different frequencies with minimal impact on traffic.

  Resource Allocation (RA) functionality;

The resource allocation feature in forward and return link implies the usage of the defined efficiency optimization algorithms to allocate the most efficient forward and return link terminal to carrier group mapping in order to optimize the overall efficiency of the link.

On the forward and return link the implemented algorithms can be used to compute the best possible (most efficient) mapping of the terminals to the defined forward link carrier or carrier groups on the return link, given a specific interference situation.

Database Access (DB) functionality;

The database access foresees the system interface to query an external database for the extraction of the interference information and the resulting interpretation and interference level computation for all forward link scenarios (scenario A and B).

Spectrum Sensing (SS-SNIR) functionality;

The spectrum sensing on the forward link has been implemented and tested as a specific technology feature that enables the interference detection. Specifically the centralized processing of the data has been implemented and the defined method to identify the interference and distinguish it from other fading events.

All these technology features have been implemented and tested in the context of the CORASAT project. These implemented functions are implemented as technology feasibility demonstrations in the context of the CORASAT project. The promising results and with further testing and refining of the implemented functions, these can be included in future releases of specific products, based on requirements from customers.

8.3.5.3 Opportunities

The significant increase in end-to-end capacity of the next generation of high throughput satellite systems for broadband access will increase the market and the satellite access opportunities for future systems.

The development of an end-to-end system that is capable of exploiting the shared frequency bands 17.3-17.7GHz and 17.7-19.7GHz as well as 27.5-29.5GHz.

8.3.5.4 Progress and Outcomes

The development of a demonstration platform for the key technology outcomes are defined and implemented within CORASAT in the year 2015.

Table 26 lists the exploitation plan of the project in terms of specific technology developments that are planned to be executed within the scope of WP4 of the project for the demonstration platform and which may have subsequent potential usage in related products.

Table 26 - Exploitable knowledge for NTC.

	Exploitable knowledge/products	Sector of application	Timetable	Patents or other IPR protection
1	Wideband demodulators (MCD) covering 140MHz for the return link.	Feature for Broadband two-way access platforms.	Implemented in technology prototype 2015	N.A. IPR as implementation know how proprietary

2	Channel emulator setup as a stand-alone test unit. (Stand-alone 1U satellite link test device)	Test equipment product Lab test context for all equipment level tests for satellite links.	Implemented and validated unit for further testing in 2015.	N.A. IPR as implementation know how proprietary
3	Spectrum sensing feature to detect interference (based on defined SS-SNIR method).	Feature for the usage in the context of broadband access networks. Detection and monitoring of interference from different sources possible.	Demonstrator implemented in technology demonstration within 2015. Implementation on broadband access network possible in 2016.	N.A. Implementation know how proprietary
4	Dynamic capacity assignment on the forward link, (DCA forward link). Centralized network control center (NCC) capable of allocating capacity on the basis of the entire network channel states.	Feature for Broadband access platform. To be used in the context of beam switching applications.	Demonstrator implemented in lab technology demonstration in 2015. Planned to be implemented in commercial product in 2016.	N.A. Implementation know how considered as proprietary knowledge
5	Dynamic capacity assignment, (DCA return link). Flexible capacity allocation on the return link carriers with a centralized control over the capacity.	Feature for Broadband access platform.	Demonstrator implemented in lab technology demonstration in 2015.	N.A. Implementation know how considered as proprietary knowledge

8.3.6 University of Surrey

8.3.6.1 Mission and Vision

The University of Surrey is a research based organization with a mission to extend knowledge and to exploit the knowledge in collaboration with industry and to its teaching programmes. Knowledge gained from research is intellectual property that we exploit as background in bidding for additional research contracts. We also exploit the knowledge in collaboration with industrial partners or directly via spin off activities. The University has an experienced team of enterprise staff to help discover and exploit the IPR. New knowledge is also incorporated in our teaching programmes at post and undergraduate level in order to enhance our attractiveness to students. As UK universities are assessed on a five yearly period the research output in terms of published papers in good quality journals is an important KPI in our activities.

8.3.6.2 Exploitable Knowledge

Exploitable knowledge developed by UNIS in the framework of the CoRaSat project is summarized in Table 27.

Table 27 - Exploitable knowledge for UNIS.

	Exploitable knowledge/products	Sector of application	Timeframe	Patents or other IPR protection
1	Data base modelling software	Regulation and satellite operators	Software available.	Know how
2	Spectrum mapping tables	Regulation, satellite users and operators	Within a year	Know how
3	Data base statistics	Regulation and research	Some available but developing.	Published in part

8.3.6.3 Opportunities

We see opportunities to develop the software in collaboration with partners to make available to Regulators within Europe for evaluation of the interference at any location. The need for a data base input within a specific country can be managed by the regulator or confidentially made available to a third party. We see a service of provision of spectrum maps that can be used by satellite operators or by potential users to guide decisions as to siting of terminals. The spectrum data can be made available to satellite operators for use in their resource management infrastructure.

Further work on data base statistics is an area of research interest and the exploitation would be in the application for additional research funds.

8.3.6.4 Progress and Outcomes

We are in the process of validation of our software and creating awareness amongst the community. Interfaces are being developed to make the outputs of the software usable by players in the sector. Once the CEPT have decided on how they will proceed with the production of the EU interference maps and if this decision is to go with a trusted third party we will contact commercial companies to offer our expertise and possibly license the software. The knowledge gained in this work has been used as background in the bidding for two additional research contracts. We have used the software in one awarded contract. We have published a number of conference research papers and a journal paper. We have also been invited and made some presentations to regulatory organisations on the outcome of the work.

9 CONCLUSIONS

This deliverable presented the final dissemination report within the three years of the CoRaSat Project, including dissemination materials elaborated, report on raising awareness activities to relevant stakeholders. Moreover, the exploitation plan for each Partner has also been outlined.

Based on the dissemination activities reported in this deliverable, the CoRaSat Consortium actually succeeded in raising awareness on CR-based Satellite Communication in the academic, regulatory, industrial, and scientific fora. This is substantiated by the relevant number of dissemination activities and publications, which exceed the target objectives reported in the DoW. In particular:

- The CoRaSat Partners have published 25 conference papers, 6 journal papers, and a book chapter, exceeding the number of publications targeted within the DoW (12 conference papers, 6 journal papers).
- The CoRaSat Partners collaborated to 8 workshops, significantly raising awareness on CR techniques applied to satellite systems. This is a valuable result, as 3 workshops were targeted in the DoW. It is worthwhile highlighting, in particular, the organization of a dedicated workshop at ICC 2015, which focused on CR in satellite and terrestrial systems frequency sharing. This workshop attracted 13 papers and 2 keynotes and contributed to a successful full day workshop at the IEEE flagship conference. Moreover, a workshop with the ESA project FREESTONE was also organized.
- The Consortium has also been extremely active towards the regulatory community, by regularly presenting the outcomes of the CoRaSat project to 6 regulators with respect to the 4 targeted regulators in the DoW. Such deep involvement of the Partners in the regulatory framework resulted in an invitation to join the CEPT FM44 group that has now taken our database concept to the point of engaging all EU regulators, and in the inclusion of the CoRaSat work to a CEPT SE40 report currently sent out for consultation.
- Within the standardization community, the Consortium has submitted an SRDoc to the ETSI SES-SCN group, which was published and is now working its way through updates involving satellite operators and equipment manufacturers. Moreover, the CoRaSat Partners also have engaged the IEEE 1900 standards group. These activities allowed to achieve the objectives related to the standardization framework agreed in the DoW.
- Finally, the Partners also regularly presented the outcomes of the CoRaSat project to EC Clusters, ESA, and other technology platforms.

Based on the above observations, and on the detailed dissemination activities reported in this deliverable, the CoRaSat project has achieved the challenging objective to **raise awareness on CR-based satellite systems, paving the way for flexible and smart spectrum usage in satellite/terrestrial networks.**

10 REFERENCES

[1]. K. Liolis, G. Schlueter, J. Krause, F. Zimmer, L. Combelles, J. Grotz,Â S. Chatzinotas, B. Evans, A. Guidotti, D. Tarchi, and A. Vanelli-Coralli, "Cognitive Radio Scenarios for Satellite Communications: The CoRaSat Approach," 2013 Future Network and Mobile Summit (FuNeMS), 3-5 July 2013, Lisboa, Portugal, URL: http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6633534.

[2]. D. Tarchi, A. Guidotti, V. Icolari, A. Vanelli-Coralli, S.K. Sharma, S. Chatzinotas, S. Maleki, B. Evans, P. Thompson, W. Tang, J. Grotz, "*Technical challenges for cognitive radio application in satellite communications*,"2014 9th International Conference on Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM), pp. 136-142, 2-4 June 2014, Oulu, Finland, DOI:10.4108/icst.crowncom.2014.255727

[3]. N. Chuberre, B. Evans, A. Vanelli-Coralli, J. Krause, J. Grotz, S.K. Sharma, "*FP7 PROJECT CoRaSat intermediate results and standardization strategy*", 2014 European Conference on Networks and Communications (EuCNC) - Workshop on Radio Access and Spectrum, Bologna, Italy, 23 Jun. 2014 [download pdf]

[4]. S. Maleki, S. Chatzinotas, S.K. Sharma, A. Guidotti, D. Tarchi, A. Vanelli-Coralli, W. Tang, B. Evans, J. Grotz, K. Liolis, J. Krause, N. Chuberre, "*Cognitive radio for Ka band satellite communications*," 32nd AIAA International Communications Satellite Systems Conference (ICSSC 2014), 4-7 August 2014, San Diego, CA, USA, DOI:10.2514/6.2014-4327

[5]. Tsakmalis, S. Chatzinotas; B. Ottersten, "Automatic Modulation Classification for Adaptive Power Control in Cognitive Satellite Communications", 2014 7th Advanced Satellite Multimedia Systems Conference and the 13th Signal Processing for Space Communications Workshop (ASMS/SPSC), 8-10 September 2014, Livorno, Italy, DOI:10.1109/ASMS-SPSC.2014.6934549

[6]. S.K. Sharma, S. Maleki, S. Chatzinotas, J. Grotz, B. Ottersten, "*Implementation Issues of Cognitive Radio Techniques for Ka-band (17.7-19.7 GHz) SatComs*,"2014 7th Advanced Satellite Multimedia Systems Conference and the 13th Signal Processing for Space Communications Workshop (ASMS/SPSC), 8-10 September 2014, Livorno, Italy, DOI:10.1109/ASMS-SPSC.2014.6934550

[7]. A. Vanelli-Coralli, A. Guidotti, D. Tarchi, S. Chatzinotas, S. Maleki, S. K. Sharma, N. Chuberre, B. Evans, M. Lopez-Benitez, W. Tang, J. Grotz, K. Liolis, "Cognitive Radio Scenarios for Satellite Communications: The CoRaSat Project," in "Cooperative and Cognitive Satellite Systems," Eds. S. Chatzinotas, B. Ottersten and R. de Gaudenzi, Elsevier, London, UK, 2015, DOI:10.1016/B978-0-12-799948-7.00010-4

[8]. W. Tang, P. Thompson, and B. Evans, "*Frequency Band Sharing between Satellite and Terrestrial Fixed Links in the Ka band*," 20th Ka and Broadband Communications, Navigation and Earth Observation Conference, 1-3 October 2014, Vietri/Salerno, Italy, URL:http://proceedings.kaconf.org/papers/2014/ka21_1.pdf

[9]. A. Mohamed, M. Lopez-Benitez, and B. Evans, "*Ka band satellite terrestrial co-existence: A statistical modelling approach*," 20th Ka and Broadband Communications, Navigation and Earth Observation Conference, 1-3 October 2014, Vietri/Salerno, Italy, URL:http://proceedings.kaconf.org/papers/2014/ka21_3.pdf

[10]. V. Icolari, D. Tarchi, A. Vanelli-Coralli, and M. Vincenzi, "*An energy detector based radio environment mapping technique for cognitiveÂ satellite systems*," IEEE Globecom 2014, December 2014, Austin, TX, USA, DOI:10.1109/GLOCOM.2014.7037247

[11]. E. Lagunas, S. K. Sharma, S. Maleki, S. Chatzinotas, J. Grotz, J. Krause, and B. Ottersten, "*Resource Allocation for Cognitive Satellite Uplink and Fixed-Service Terrestrial Coexistence in Ka-band*," 2015 10th International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM), 21-23 April 2015, Doha, Qatar [download pdf]

[12]. W. Tang, P. Thompson, and B. Evans, "*A Database Approach to Extending the Usable Ka Band Spectrum for FSS Satellite Systems*," The 7th International Conference on Advances in Satellite and Space Communications (SPACOMM) 2015, 19-24 April 2015, Barcelona, Spain

[13]. W. Tang, P. Thompson, and B. Evans, "*Frequency Sharing between Satellite and Terrestrial Systems in the Ka Band: A Database Approach*," 2015 IEEE International Conference on Communications (ICC), pp. 2470-2475, 8-12 June 2015, London, UK

[14]. S. K. Sharma, S. Maleki, S. Chatzinotas, J. Grotz, J. Krause, and B. Ottersten, "*Joint Carrier Allocation and Beamforming for Cognitive SatComs in Ka-band (17.3-18.1 GHz)*," 2015 IEEE International Conference on Communications (ICC), pp. 2476-2481, 8-12 June 2015, London, UK

[15]. V. Icolari, A. Guidotti, D. Tarchi, and A. Vanelli-Coralli, "*An Interference Estimation Technique for Satellite Cognitive Radio Systems*," 2015 IEEE International Conference on Communications (ICC), pp. 2495-2500, 8-12 June 2015, London, UK

[16]. C. Kourogiorgas, A. D. Panagopoulos, and K. Liolis, "*Cognitive Uplink FSS and FS Links Coexistence in Ka-band: Propagation based Interference Analysis*," IEEE ICC 2015, Workshop on Cognitive Radios and Networks for Spectrum Coexistence of Satellite and Terrestrial Systems (CogRaN-Sat), pp. 9735-9740, 12 June 2015, London, UK

[17]. P. Thompson and B. Evans, "*Analysis of Interference between Terrestrial and Satellite Systems in the Band 17.7-19.7 GHz*," IEEE ICC 2015, Workshop on Cognitive Radios and Networks for Spectrum Coexistence of Satellite and Terrestrial Systems (CogRaN-Sat), pp. 9729-9734, 12 June 2015, London, UK

[18]. V. Icolari, D. Tarchi, A. Guidotti, and A. Vanelli-Coralli, "*Beam Pattern Allocation Strategies for Satellite Cognitive Radio Systems*,"Â IEEE ICC 2015, Workshop on Cognitive Radios and Networks for Spectrum Coexistence of Satellite and Terrestrial Systems (CogRaN-Sat), pp. 9712-9717, 12 June 2015, London, UK

[19]. S. K. Sharma, E. Lagunas, S. Maleki, S. Chatzinotas, J. Grotz, J. Krause, and B. Ottersten, "*Resource Allocation for Cognitive Satellite Communications in Ka-band (17.7-19.7 GHz)*," IEEE ICC 2015, Workshop on Cognitive Radios and Networks for Spectrum Coexistence of Satellite and Terrestrial Systems (CogRaN-Sat), pp. 9706-9711, 12 June 2015, London, UK

[20]. A. Guidotti, V. Icolari, D. Tarchi, A. Vanelli-Coralli, S. K. Sharma, E. Lagunas, S. Maleki, S. Chatzinotas, J. Grotz, J. Krause, E. Corbel, B. Evans, and P. Thompson, "*Spectrum Awareness and Exploitation for Cognitive Radio Satellite Communications*," 2015 European Conference on Networks and Communications (EuCNC), pp. 16-20, 29 June-2 July 2015, Paris, France

[21]. B. Evans, P. Thompson, E. Lagunas, S. K. Sharma, D. Tarchi, and V. Icolari, "*Extending the usable Ka band spectrum for satellite communications: The CoRaSat project*," 7th EAI International Conference on Wireless and Satellite Systems (WiSATS), 6-7 July 2015, Bradford, UK

[22]. D. Tarchi, V. Icolari, J. Grotz, A. Vanelli-Coralli, and A. Guidotti, "*On the feasibility of Interference Estimation Techniques in Cognitive Satellite Environments with Impairments*," 7th EAI International Conference on Wireless and Satellite Systems (WiSATS), 6-7 July 2015, Bradford, UK

[23]. A. Guidotti, D. Tarchi, V. Icolari, A. Vanelli-Coralli, and G. E. Corazza, "*Spectrum awareness techniques for 5G Satellite Communications*," 23rd European Signal Processing Conference (EUSIPCO), accepted for publication, 31 August-4 September 2015, Nice, France

[24]. E. Lagunas, S. K. Sharma, S. Maleki, S. Chatzinotas, and B. Ottersten, "*Impact of terrain aware interference modelling on the throughput of cognitive Ka-band satellite systems*," 21st Ka and Broadband Communications Conference, accepted for publication, 12-14 October 2015, Bologna, Italy

[25]. P. Thompson and B. Evans, "*Extending the spectrum for Ka band satellite systems in the shared bands via a database approach*," 2015 21st Ka and Broadband Communications Conference, accepted for publication, 12-14 October 2015, Bologna, Italy

[26]. E. Lagunas, S. K. Sharma, S. Maleki, S. Chatzinotas, and B. Ottersten, "*Power Control for Cognitive Satellite Uplink in Ka-band*," 2015 IEEE 82nd Vehicular Technology Conference (VTC) Fall, accepted for publication, 6-9 September 2015, Boston, UK

[27]. L. Arienzo, D. Tarchi, "*Statistical Modeling of Spectrum Sensing Energy in Multi-Hop Cognitive Radio Networks*," IEEE Signal Processing Letters, vol. 22, no. 3, pp. 356-360, March 2015, DOI:10.1109/LSP.2014.2360234

[28]. S. Maleki, S. Chatzinotas, B. Evans, K. Liolis, J. Grotz, A. Vanelli-Coralli, and N. Chuberre, "*Cognitive spectrum utilization in Ka band multibeam satellite communications*," IEEE Communications Magazine, vol. 53, no.3, pp.24-29, March 2015, DOI:10.1109/MCOM.2015.7060478

[29]. S. Maleki, S. Chatzinotas, J. Krause, K. Liolis, B. Ottersten, "*Cognitive Zone for Broadband Satellite Communications in 17.3 -17.7 GHz Band*," IEEE Wireless Communications Letters, vol.4, no.3, pp.305-308, June 2015, DOI:10.1109/LWC.2015.2411597

[30]. S. Maleki, G. Leus, S. Chatzinotas, and B. Ottersten, "*To AND or To OR: On Energy-Efficient Distributed Spectrum Sensing with Combined Censoring and Sleeping*," IEEE Transactions on Wireless Communications, accepted for publication, April 2015, DOI:10.1109/TWC.2015.2422304

[31]. E. Lagunas, S. K. Sharma, S. Maleki, S. Chatzinotas, and B. Ottersten, "*Resource Allocation for Cognitive Satellite Communications with Incumbent Terrestrial Networks*," submitted to IEEE Transactions on Cognitive Communications and Networking, 2015

[32]. W. Tang, P. Thompson, and B. Evans, "*A database approach to extending the usable spectrum for FSS satellite systems*," invited paper to the International Journal on Advances in Telecommunications, submitted July, 2015

11 DEFINITIONS, SYMBOLS AND ABBREVIATIONS

AGCOM	*Autorità per le Garanzie nelle Comunicazioni*
AIPAS	*Associazione Italiana PMI per l'Aerospazio*
ANFR	*Agence Nationale des FRéquences*
ARCEP	*Autorité de Régulation des Communications Électroniques et des Postes*
ASAS	Association for Space-based Applications and Services
BELSPO	Belgian Federal Science Policy Office
BEREC	Body of European Regulators of Electronic Communications
BNetzA	*Bundesnetzagentur*
CEPT	*Conférence européenne des administrations des postes et des Telecommunications*
CERP	*Comité européen des régulateurs postaux*
CNES	*Centre National d'Études Spatiales*
CR	Cognitive Radio
CUS	Collective Use of Spectrum
DYSPAN	Dynamic Spectrum Access Network
ECC	Electronic Communications Committee
ECO	European Communications Office
ERC	European Radiocommunications Committee
ESOA	European Satellite Operators' Association
ETNO	European Telecommunications Network Operators'
ETP	European Technology Platform
ETSI	European Telecommunications Standards Institute
FM	Frequency Management
FP7	Seventh Framework Programme
GVF	Global VSAT Forum

IBPT	*Institut Belge des services Postaux et des Télécommunications*
ICT	Information and Communications Technologies
IEEE	Institute of Electrical and Electronics Engineers
ILR	*Institut Luxembourgeois de Régulation*
ISI	Integral SatCom Initiative
LSA	Licensed Shared Access
NEM	Networked & Electronic Media
ITU	International Telecommunication Union
Ofcom	Office of Communications
RDI	Research Development and Innovation
RRS	Reconfigurable Radio Systems
RSC	Radio Spectrum Committee
RSPG	Radio Spectrum Policy Group
RSPP	Radio Spectrum Policy Program
SatCom	Satellite Communications
SE	Spectrum Engineering
SIG	Special Interest Group
SME	Small and Medium Enterprise
STREP	Specific Targeted Research Project
UKISC	United Kingdom Industrial Space Committee
WG	Working Group
WRC	World Radiocommunication Conference

12 DOCUMENT HISTORY

Rel.	version	Date	Change Status	Author
1	0	30/09/15	First Release to the European Commission	UNIS