EXECUTIVE SUMMARY

IODISPLAY

Prepared by:	IODISPLay team
Approved by:	Giovanni Binet
Authorized by:	Pablo Colmenarejo

Code:	GMV-IODISPLAY-ExSum
Version:	1.0
Date:	27/06/2016
Internal code:	21627/16 V1/16

© GMV, 2016; all rights reserved

TABLE OF CONTENTS

 © GMV 2016; all rights reserved

LIST OF TABLES AND FIGURES

 © GMV 2016; all rights reserved

1. INTRODUCTION

1.1. PURPOSE

This document is the Executive Summary of the H2020 IODISPLay project, and it contains the result of the activities carried out during the project.

1.2. SCOPE

This document is the technical note deliverable ExSum in the frame of the WP6000 of the project (Management).

1.3. DISSEMINATION LEVEL OF THIS DOCUMENT

This document is to be considered as Public.

1.4. ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Table 1-1 Acronyms

Acronym	Definition
COTS	Commercial off The Shelf
GEO	Geostationary orbit
IOD	In-Orbit Demonstration
IOV	In-Orbit Validation
LEO	Low Earth Orbit
MITO	Missionization TOol
SSA	Space Situational Awareness
SST	Space Surveillance and Tracking
SW	Software
TBC	To Be Confirmed
TBD	To Be Defined
TRL	Technology Readiness level

 © GMV 2016; all rights reserved

2. REFERENCES

2.1. APPLICABLE DOCUMENTS

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]:

Table 2-1 Applicable Documents

Ref.	Title	Code	Version	Date
[AD.1]	IODISPLay grant agreement and its annexes (grant 640253)	Ref. Ares(2014)3646475	1.0	03/11/2014

2.2. REFERENCE DOCUMENTS

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.X]:

Table 2-2 Reference Documents

Ref.	Title	Code	Version	Date
[RD.1]	IODISPLAY selected IOD/IOV technologies	GMV-IODISPLAY-D1.1	1.0	30/04/2015
[RD.2]	IOD commercial market status and perspectives	VVA-IODISPLAY-D1.22	2.0	10/09/2015
[RD.3]	IOD/IOV dedicated platforms review	INTA-IODISPLAY-D2.1	1.0	02/05/2015
[RD.4]	IOD/IOV launchers analysis	GAUSS-IODISPLAY-D2.2	1.0	29/05/2015
[RD.5]	Carrier requirements per IOD technology	GMV-IODISPLAY-D3.1	1.0	01/08/2015
[RD.6]	Available IOD carrier resources	INTA-IODISPLAY-D3.2	1.0	28/12/2015
[RD.7]	IOD MITO infrastructure	GMV-IODISPLAY-D3.3	1.0	31/07/2015
[RD.8]	IOD MITO populated	GMV-IODISPLAY-D3.4	1.0	15/01/2016
[RD.9]	IOD/IOV mission portfolio and IOD service model	GMV-IODISPLAY-D4.1	1.0	04/04/2016
[RD.10]	IOD/IOV selected missions requirements	GMV-IODISPLAY-D4.2	1.0	19/05/2016
[RD.11]	IOD/IOV selected missions preliminary design and IOD service business case	INTA-IODISPLAY-D4.3	1.0	27/06/2016
[RD.12]	IOD/IOV workshop conclusions	GMV-IODISPLAY-D5.1	1.0	10/12/2015

© GMV 2016; all rights reserved

3. THE IODISPLAY PROJECT

3.1. PROJECT GOAL

The goal of IODISPLay project could be summarized by the following statement

> *"The goal of* ***IODISPLay*** *project is to identify and down-select a portfolio of In-Orbit Demonstration (IOD) missions achievable in the H2020 timeframe, through assessing the current European IOD needs and capabilities (in terms of technologies, carriers and launchers), as well as the potential of having a commercial IOD service."*

The project has been funded under the H2020 Space Call "COMPET-05-2014 – In-Orbit Demonstration / Validation.

3.2. CONSORTIUM

The IODISPLay consortium is formed by:

- GMV Aerospace and Defence (GMV, Spain), which is the project coordinator, as well as the responsible of the collection of IOD technologies, the definition of the IOD mission portfolio and of the IOD commercial service scheme
- Instituto Nacional de Técnica Aeronáutica (INTA, Spain), which is the system engineer of the study and responsible of carriers identification
- Valdani, Vicari e Associati (VVA, Italy), responsible of the analysis of the IOD market and of the business plan of the IOD commercial service
- Group of Astrodynamics for the Use of Space Systems (GAUSS, Italy), responsible of the launchers identification

Figure 3-1: The IODISPLay consortium

3.3. SCHEDULE

The project started in January 2015 and concluded in June 2016 for a total duration of 18 months.

3.4. FUNDING

The project has received funding (total of 500.000 euros) from the European Union's H2020 research and innovation program under grant agreement No 640253.

 © GMV 2016; all rights reserved

4. IOD/IOV CAPABILITIES AND NEEDS IN EUROPE

In order to assess the status of IOD within Europe, the first phase of the project has been devoted to gather information from industries and R&D institutes on past and present IOD initiatives and missions. The collected information have been categorized in three different groups:

- Technologies: which includes all the "IOD/IOV payloads" that need to be demonstrated in orbit
- Carriers: which includes the spacecraft bus (current and proposed) that can give services for demonstrating or validating technologies in orbit
- Launchers: that include launch vectors (current or proposed) capable of delivering IOD missions to space

While the information on platforms and launchers has been mostly gathered through desk research, the team did an extensive active investigation on technologies that could profit from IOD, setting up a scheme (based on emails and 1-to-1 phone calls) which involved technology developers from all over Europe. For each category, specific questionnaires templates have been prepared and filled out.

4.1. TECHNOLOGIES

In our European-wide survey, a total of 154 technology proposals have been suggested for IOD by more than 70 different entities. Figure below shows the IOD proposals received per country and per type of organisation, showing a fairly good coverage of European countries and organisations.

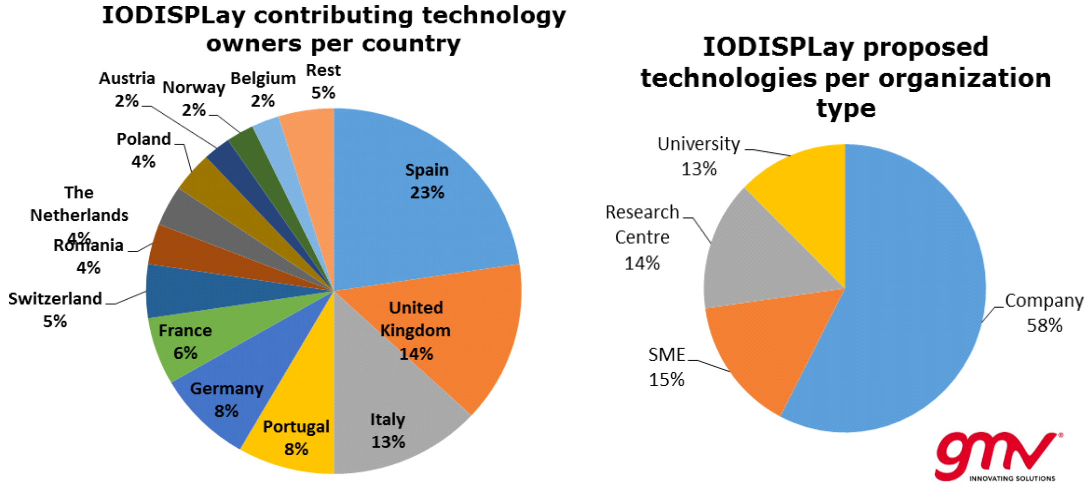

Figure 4-1: IOD technologies database - contributing countries and organisations

The following chart depicts the coverage achieved, from the received questionnaires, in terms of Technology Domains defined in ESA's Technology Tree classification. It has to be noted that some proposed technology can be categorized under more than one Technology Domain (the upper branch of ESA's Technology Tree).

Analysing Figure 4-2, it can be said that there is in general a good coverage of the whole technology domains that are part of a space mission. In particular, the following aspects should be highlighted:

- The highest interest in IOD resulted for propulsion technologies and "Space Systems Control", "Onboard data systems" and "RF Systems, payloads and Technologies", ·.
- Very good participation from technologies on "Optics" and "Optoelectronics", "Mechanisms" and "Structures".
- Limited (or absent) proposed IOD has been received on "Spacecraft Electrical Power", "System Design and Verification", "Aerothermodynamics" and "Ground Station Systems and Networks" (TD 26 is an "Others" category which has not been used).

It has to be noted that the type of technologies that has been received has been very diverse: from single subsystem technologies to complete spacecraft subsystems or payloads, going to complex techniques.

© GMV 2016; all rights reserved

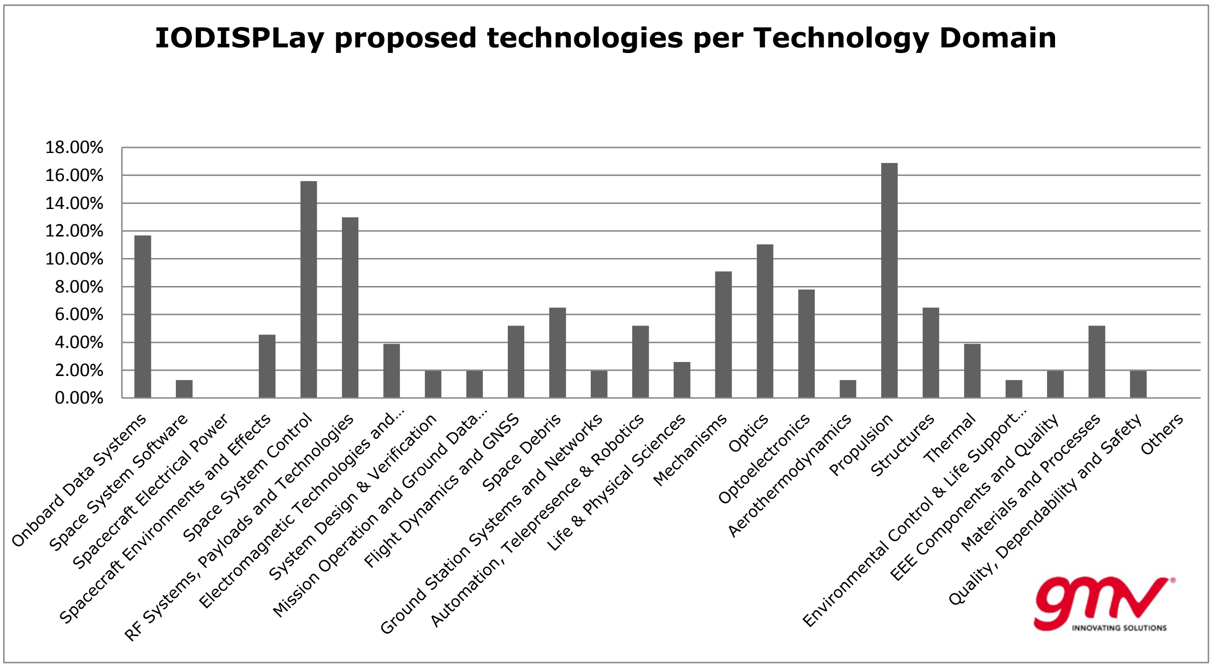

Figure 4-2: IOD technologies database – categorisation per ESA technology tree

Looking at the application of the technologies that have been proposed (the following chart depicts the technologies proposed against the ESA's Service Domains), one can see that most of them are generic ones and therefore applicable to a wide variety of space missions.

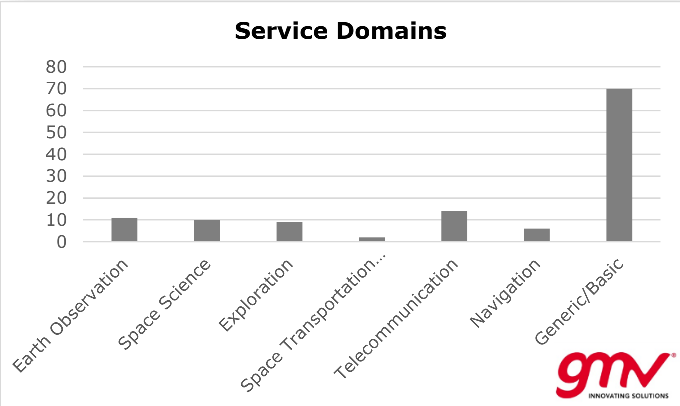

Figure 4-3: IOD technologies database – categorisation per ESA service domains

4.2. CARRIERS

A research has been carried out in order to identify carriers that could be applicable to an IOD mission. Our research has focused on satellites up to the Minisat range (below 500kg), and has identified a large number of platforms with a different degree of flight heritage. Among all these platforms, detailed information on their performances and services available to IOD payloads has been gathered for a total of 30 carriers, including also modified upper stages that could offer enough resources for demonstrating/validating payloads in orbit.

4.3. LAUNCHERS

Similarly, information on current and future launchers that could be used by an IOD mission has been gathered. These include European Launch Vehicles (Ariane5, Soyuz, VEGA as well as the in-development Ariane6), as well as other interesting launches for small satellites like DNEPR or PSLV. For the selected launch vehicles, the launch manifest up to 2020 has been collected.

 © GMV 2016; all rights reserved

4.4. THE DATABASE AND THE IOD MISSIONISATION TOOL

All the retrieved information has been structured in a database, which allows browsing and comparing characteristics of the different technologies, such as the requirements that these technologies impose on a carrier for their demonstration in orbit.

The information is stored in tables and then ready by a script that presents to the user html reports. Different technologies can be combined together into "IOD mission configurations", which also present to the user which carriers are compatible with the selected technologies combinations and the remaining margins. This can be done with the Missionisation Tool (MITO tool), which can help the user to quickly assess the main characteristics (mass, power, pointing accuracy, ROM price) of different IOD mission configurations. Also, the tool suggests additional technologies that may be included in order to use the spare space on the selected carrier for a given IOD mission configuration. Similarly, the applicable launchers (in terms of mass, orbit and fairing dimensions) are suggested to the user.

In addition, the user can give critical assessment of the different technologies in order to have a further evaluation of each technology (in addition to the data contained in the questionnaires) and produce IOD figures of merit for a mission configuration.

This tool has been prepared in order to:

- ease browsing through the IOD database
- create and evaluate IOD mission configurations
- compare different IOD mission configurations

4.5. THE IOD/IOV WORKSHOP

Organized by IODISPLay in conjunction with the other parallel H2020 IOD projects, the IOD/IOV workshop held in ESA/ESTEC in November 2015 had the following objectives:

- To gather all main IOD European actors around one single table: policy makers, industries, academia, operators, launchers
- To generate a discussion on what are the priorities for IOD
- To present the main current and recent activities related to IOD
- To propose to policy makers guidelines and priorities about future of IOD within H2020

More than 80 people were present at the event: European Commission, ESA, several National Delegations, Coordinators and Partner organisations from the Consortiums of the four H2020 IOD projects (from COMPET-5-2014), and a relevant presence of technology owners, system integrators and launcher developer and providers. The agenda can be found in the IODISPLay website. The offered presentations triggered a discussion on the priorities for IOD within Europe.

The main messages that can summarize the generated discussion are presented here below:

- The initial H2020 IOD objective is to foster a service for providing opportunities of IOD, which can enable frequent and ideally self-sustainable access to space.
- Choice of technologies to be flown will come after the definition of any IOD service (including roles) and will depend on what the Community will propose.
- Investment in critical technologies and non-dependence is needed to boost European competitiveness: the upside is that Europe is investing much more than 7 years ago.
- Return of Investment from IOD (excluding purely commercial technologies) can be achieved by demonstrating complex techniques.
- In order for an IOD to have added value, the user should be identified.
- Commercial IODs (especially telecom) already have their ways for flying, since there is a final commercial customer behind.
- In order to overcome valley of death, the solution cannot rely only on demanding money for IOD to people who don't have it. Institutional support is needed.

 © GMV 2016; all rights reserved

5. PROPOSAL FOR AN IOD/IOV SERVICE

The European Commission clearly highlighted, since the issue of the H2020 COMPET-5-2014 call, the need for Europe to make access to space possible for new technologies and innovations, by means of in-orbit demonstrations and/or validation. This would further foster competitiveness and non-dependence. IODISPLay, with its survey activity, demonstrated the existence of the so called “valley of death” (see figure below), and hence the need for a change of paradigm to solve this situation. Many technologies with a relatively high TRL (4-5), remain stuck in the TRL scale, struggling for finding funds and opportunities for further maturing their technologies and getting an affordable ticket to space in a predictable frame.

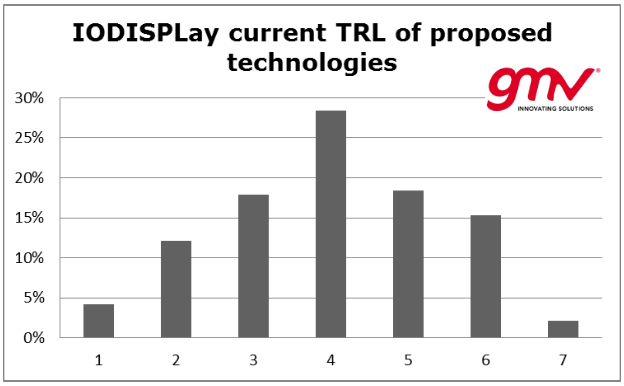

Figure 5-1: TRL Valley of death

Within IODISPLay survey, more than 150 technologies have been proposed for IOD: what can be said with a high degree of confidence is that most of these technologies, given the current possibilities, will not find their way to being demonstrated in orbit.

Also, the results of the IODISPLay consultations put under the spotlights other very relevant aspects:

- There is a high interest in IOD/IOV from technology developers;
- Many technologies are really innovative and, within their engineering and qualification models, nurse high potential, both in term of interest from institutions for scientific missions and applications and for the disruptive effect they could have on the markets, once demonstrated;
- Other technologies, for sure, are based on less innovative concepts, but they generally have a wide commercial application that could anyway enable, once flown, the opening of new competiveness scenarios (within Europe, as well as with respect to the rest of the World), as well as the creation -or conservation- of occupation and jobs, and from these the release of new potential for growth and other innovation.

All these facts give confidence that a virtuous circle is possible, if there would be a jump out of the “valley of death”. Moreover, nothing in the current situation would solve this problem.

The solution to the current situation would need to provide frequent, predictable and affordable access to space for demonstrating technologies in orbit, as also highlighted during the IOD workshop held at ESTEC in November 2015.

While currently such mechanism is not yet available as European commercial service, some IOD initiatives (mainly institutional) have tried to go in a similar direction. The German TET-1 mission has been funded by the DLR’s On-Orbit Verification programme (launched in 2012). The initial idea of this mission is that it would initiate a program with recurrent IOD missions based on the TET platform. The second TET mission however did not obtain funding from DLR (TET-2 has been studied up to phase B): currently a fully financed mission is not foreseen by DLR. Similarly, UK’s TechDemoSat (TDS, launched in 2014) initiative resulted into a single shot IOD mission.

Now DLR and UKSA are joining forces with the bi-lateral EuroIOD common initiative, with Phase A studies funded through ESA’s GSTP program. The initiative, presented at the IOD workshop, aims at bringing together the experience in TET and TDS, especially of the integrators OHB/AstroFein (TET)

 © GMV 2016; all rights reserved

and SSTL (TDS). The initiative foresees one IOD mission every two year, with a payload selection competition running in parallel with the mission definition.

ESA's Technology Flight Opportunities (under GSTP element 3) have the objective of matching payloads with satellites that offer spare room to host them. ESA acts as a middleman and provides the database that links the two parties (payload and carrier), as well as potentially financing the cost of the payload through GSTP programs. Also, ESA has a track record of successful IOD PROBA missions, implemented under full institutional funding (through GSTP programme). These missions do not have, however, the intention of being initiators or part of a service. Lastly, the Spanish SME TestInSpace has launched an initiative where IOD is possible on-board of 3U cubesat platforms, supported by a grant for the H2020 SME initiative phase 1. ESA is also now leaning towards the use of cubesats for performing IOD missions, such as the case of the GOMX-3 mission. Similarly, the UK's Space Applications Catapult has recently started an initiative for IOD using cubesats, to be deployed from the ISS.

Some generic considerations can be done about the characteristics of these mentioned past and on-going experiences:

- In the recent years the IOD problem has been tackled in under multiple and different schemes
- None of those have had or has up to date a clear commercial objective or is underlying a successful service scheme
- The TET and TDS platforms are both in the range of 120/150 kg (with around 50kg of payload), which may result in relatively high costs. Same is for PROBA missions. Focusing the service on smaller platforms could potentially lower the costs and make the price for commercial customers more appealing, though the need for large (institutional) payloads still exists
- Some of them have been deployed only at national level, without exploiting the potential of a European-wide market
- The institutional effort is thus required to setting up an IOD service scheme

5.1. THE MARKET OF AN IOD/IOV SERVICE

Within IODISPLay, it has been explored the possibility that the identified IOD schemes to be implemented within H2020 can be the first step of a commercial IOD service. In this context, a market survey for an IOD service has been carried out.

Up to now, there is a mismatch between demand and offer of IOD opportunities, both in terms of number of such opportunities vis-à-vis the level of demand and in terms of the required budget of IOD activities vis-à-vis the availability to pay by technology developers.

While institutional missions and "hosted payload" approaches provide specific opportunities, and so are also doing Cubesats for small technologies, at the time being there is no such thing as a commercial service dedicated to demonstrating technologies in-orbit.

The demand for IOD is composed by technology suppliers in the manufacturing sector, which can be grouped in two main categories: private companies and research organisations, though the vast majority of the needs arise from the companies. The need for IOD is expressed for systems, equipment and components.

The entities representing the potential demand for IOD services obviously share the same characteristics of the overall EU space industry, composed of a small number of very large system integrators and a large number of smaller companies.

Aside the obvious differences in terms of available resources and scale of the activities between these two categories of players, there are also differences in the average financial outlook, whit small companies tending to be under pressure, recording low, zero or negative profitability.

As mentioned above, the companies contacted within the project expressed a strong interest in IOD. After removing outliers, the average budget foreseen as necessary for IOD has been indicated to be around 720 thousand EUR.

Further analysis, carried out through in-depth interviews with selected technology developers, revealed that companies that are not system integrators often develop their products and components up to a certain stage, and then wait for opportunities to materialize in order to finalise the progression of TRL. Reasons behind are many:

 © GMV 2016; all rights reserved

- Some technologies are driven by institutional needs rather than by commercial objectives. In this case, an institutional player requires the technology and funds its development through contracting. Thus, technology developers focus on achieving the TRL steps required in the contract and expect the institutional player to fund the IOD activity, if and when they deem necessary;
- Some technologies are components meant to be tested as a part of a whole system. In this case, it is the system integrator, not the technology developer that will move to the IOD activity, only after finalising the development of the system;
- Some technologies have a commercial potential but the technology developer does not have the partially or fully the necessary budget for IOD – which is due to a combination of:
    - the overall low profitability figures of medium and small space companies;
    - the lack of IOD opportunities, which generates a "chicken and egg" issue: companies do not set aside budget for IOD activities within the overall resources for technology development because they are not confident they will identify opportunities. Some of these companies try then to identify potential customers to which they can propose to provide the technology for free in case the customers are available to fly it.

Developing an IOD service is particularly important to solve this third issue. Some technologies might have a high commercial potential which remains tapped.

An IOD service is therefore is expected to be able to:

- Provide a cost-effective opportunity for technology developers which are currently missing opportunities for IOD; and
- Solve the "market failure" faced by developers of technologies with promising commercial potential, which are stopped by the lack of IOD budget.

Dedicated in-depth interviews with selected technology developers revealed that, in the presence of such a service, these companies would be able to pay, with the rough order of magnitude of their willingness to pay being 200,000 EUR /Kg.

5.2. PROPOSAL OF AN IOD/IOV SERVICE SCHEME

For solving the current IOD situation, the IODISPLay Team proposes that the *scheme* that should offer affordable, frequent and predictable access to space to technologies should be implemented as a European IOD Service with the following objectives:

- To bring into the IOD Service Business Units a private company (commercial) approach: it means targeting competitiveness (lower prices by competition), making decisions oriented to complying and price-effective solutions, moving cost management from design-to-cost towards target costing with fair margins.
- To stimulate competition in access to space through a politic of procurement and outsourcing (Launch and Carriers) based on negotiations, agreements and pricing; the objective is to bring prices down and open the market.
- To find and open channels for enabling funding mechanisms and interest from investors for supporting technology owners in their road to IOD/IOV
- To provide a virtuous cooperative circle for spreading awareness of needs and opportunities as well as ease finding partnerships and networking between stakeholders and actors.

Based on this, the IODISPLay team has designed an IOD service which acts as an intermediary between the IOD clients and the providers of the basic IOD services. The IOD service provider would offer both IOD strategy services (matchmaking, intelligence, database maintenance...) as well as the implementation of IOD missions. The basic scheme is reported here below in figure.

 © GMV 2016; all rights reserved

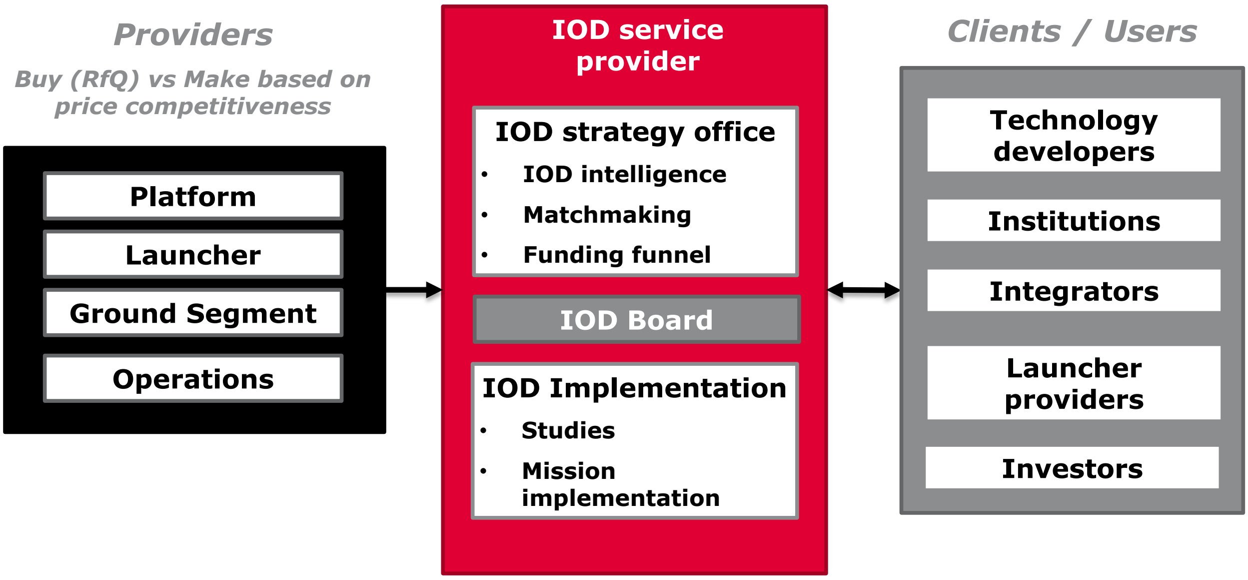

Figure 5-2: IOD service scheme

In the figure above, the IOD service provider can be seen at the centre, with the main elements offered within the red block. On the left side, all the building blocks needed by the service provider to implement one IOD mission, which will be procured commercially (or in a buy vs make decision, depending on the capabilities of the service provider). On the right side, the clients that would use the services of the IOD provider.

The IOD service provider will help solving the current European IOD situation by providing IOD opportunities that are:

- Predictable, allowing planning and set aside IOD resources in the development roadmap of a new technology;
- Frequent, maximising opportunities for flying technologies (1-2 per year as goal)
- Affordable, as limited resources impose that an IOD service can become a reality only if available at low cost

5.2.1. CLIENTS OF THE IOD SERVICE

The IOD service is intended to be offered to three different customer segments, each one with its specific needs and expectations:

- **Technology Owners** / Developers: their main needs are related to the improvement and validation of their technologies. More in detail, they are interested in:
  - Further develop and progress on their technologies to be ready for IOD;
  - Fly their technology to give flight heritage (IOV) or conduct experiments / measurements (IOD);
  - Develop partnership with key stakeholder and access to financing
  - Highlight their technologies to policy makers

  It is important to underline that this segment contains players with very different goals, as well as availability and willingness to pay.
- **Public Institutions**: public institutions are mainly interested in increasing the competitiveness of European technologies and in effectively addressing public investments. Thus they need to:
  - Foster European technologies competitiveness through supporting an IOD service;
  - Organize an IOD mission for a specific technology or technique;
  - Fill-up the capacity of contracted launches in order to maximize the output of public investments;
  - Join and be part of an aggregated board to steer IOD strategy

© GMV 2016; all rights reserved

- **System Integrators** (carrier and launcher developers): they are mainly interested in finding technologies that can complete/integrate their systems or lower their costs, or sharing their mission costs;
- **Launcher Providers / Satcom Operators**: their main goal is to share a mission's costs.

5.2.2. BUSINESS UNITS AND OFFERED SERVICES

The new entity would be organized in two different business units:

- **The IOD Strategy Office**, whose goal is to be a "one-stop shop" for the clients – both public and private – needing support in all the activities prior to the implementation of a mission, including the access to funding. The offered services are detailed in the table below.

Table 5-1 IOD strategy office offered services

Offered service	Description
IOD technology intelligence	Consists in (i) the overview and assessment of technologies status, and (ii) the provision and update of TRL/IOD status of technologies to public institutions. At the same time technology developers are able to showcase their technologies. This type of work is similar to what has been carried out within the IODISPLay project in the data retrieval stage
Matchmaking of IOD opportunities	Consists in the identification and matching of technologies/actors for specific IOD or technology needs, providing information and awareness of opportunities. This service allows the following key players to get in contact. On one side there are (i) public institutions that interested in finding or developing a strategic technology; (ii) LSIs that need to integrate their systems with a missing technology; (iii) Launcher providers and Satcom operators that are interested in sharing mission costs. On the other side there are technology developers that are looking for partnerships/collaboration. The service may be activated by each one of these players
Matchmaking of investment opportunities	Consists in the identification of potential private investors interested in supporting the development of a specific technology or IOD Mission. The objective of this service is to: (i) allow technology developers and launchers to have the funding needed to complete their activities; (ii) enable investors to allocate their resources in potentially profitable initiatives, thanks to the expected future commercial application of the technologies tested

- **The IOD Service Implementation Office**, whose goal is to support the clients in all the activities related to the implementation of a mission, starting from the analysis of feasibility. The offered services are detailed in the table below

Table 5-2 IOD service implementation office offered services

Offered service	Description
Feasibility studies	Carry out studies to assess the feasibility of an IOD mission (either as dedicated or as a hosted payload), in order to present a programmatic dossier that includes the main mission performances and characteristics, its schedule and costs.
Implementation of full IOD mission	Implementation of full IOD mission in a scheme that can guarantee regular and predictable access to space, through the following activities (either subcontracted or carried out internally, depending on the most competitive alternative): system engineering; launch opportunity procurement; technologies selection; platform sourcing; system assembly integration and testing; ground segment and operations services; overall mission management and funnel of different funding sources, in terms of selection of potential investors interested in supporting the development of specific technologies or IOD missions

© GMV 2016; all rights reserved

It is important to underline that the business units can be operational within a different time frame. Additionally, an IOD board composed by all main stakeholders (including institutions that could monitor the use of any public funding and ensure successful implementation) will steer the service strategy.

Finally, transversal to both business units an **IOD steering board** will also be part of the IOD service, composed by institutions (EC, ESA, EDA and national delegates) and industry representatives. The board will profit from the intelligence generated by the IOD office and coordinate a European-wide IOD policy by helping set the priorities for IOD missions and influence the decision on the payloads to be flown under institutional support (i.e. while not overstepping in the commercial activities of the IOD service provider). The board will also monitor any potential conflict of interest and market abuse from the IOD service provider.

5.2.3. REVENUE MODELS

The revenue model of each service has been defined in order to ensure:

- the **overall economic and financial viability** of both the business units within a reasonable time frame. The different services are going to generate different levels of profitability, depending on many factors, such as the actual and perceived added value provided to the clients and the implementation timeframe. This implies that the contribution of each service to the overall performance of the IOD service can vary significantly.
- that the **remuneration** due for the services provided by the IOD service is perceived as **fair and competitive** by the potential customers, accordingly to their budget, needs and willingness to pay.

The following revenue streams have been identified from each client:

Table 5-3 Revenue streams

Client / Offered service	Technology Owner	Public institution	LSIs, Launchers, satcom operators
IOD technology intelligence		Payment of success fee Long term procurement	
Matchmaking of IOD opportunities	Payment of success fee	Payment of success fee	Payment of success fee
Matchmaking of investment opportunities	Payment of success fee		
Feasibility studies		Payment of daily fee	Payment of daily fee
IOD mission implementation	Payment of ticket to space	Funding of parts of the mission Contribution in kind to mission elements	

This revenue models imply the existence of a fully commercial IOD service provider. In the following sections, the business case will be analysed given the current market situation, and on how the emergence of such service could be fostered through institutional support.

 © GMV 2016; all rights reserved

5.3. MISSION PORTFOLIO OF AN IOD/IOV SERVICE

In preparing the concept for an IOD/IOV service, the IODISPLay team took into account all the information gathered about the technologies proposed for IOD/IOV, in order to obtain the following:

- A number of promising IOD/IOV mission concepts, based on the interest that has been perceived during the data collection process, communications with policy makers and applications to future applications or missions
- Statistics about the market segment of technologies that should be hosted on a mission to be offered by the IOD service, and hence identify which mission options should be made available to an IOD customer

Ultimately, this has supported the identification of the portfolio of mission that should be encompassed by an IOD service.

The following table lists the most promising 13 IOD/IOV mission concepts that have been identified in IODISPLay by analysing the IOD database. This has been done taking advantage of the Missionization Tool.

Ideally, this exercise should be done/repeated regularly, as new technologies arise with time.

Note that, while each mission is dedicated to a specific topic, other technologies have also been identified to fly as IOD/IOV companions.

Table 5-4 IOD mission portfolio

#	Mission Name	IOD/IOV Concept and Objectives
1	Space-based Debris Observation and Identification	The proposed mission aims at providing the required infrastructure for demonstrating different techniques of space based optical observation of space debris (both monitoring and tracking of Earth orbiting objects) together with the on ground infrastructures for data processing. Space based observations are needed to build up ground databases, maintain them and track specific targets. The mission could be a precursor of a European Flagship for SSA and Space Debris Observation.
2	Rendezvous and Capture demonstration mission	The proposed IOD mission aims at demonstrating a number of techniques that would enable innovative rendezvous and capture technologies that would be beneficial for active debris removal, in-orbit servicing and Exploration missions. The proposed mission would require an active spacecraft (chaser) hosting the technologies to be demonstrated and a target
3	THz / IR Upper Atmosphere Sounding	The mission proposes to demonstrate a low cost upper atmosphere sounder; provide scientific data to be bench-marked against existing atmosphere data sets and provide verification and experience for other future science missions / instrument
4	Small SAR mission	The Earth Observation mission aims at demonstrating a new SAR concept oriented to small satellites, and for potential application to formation flying and constellations. Continuous Wave (CW) Radar requires much less power to operate than conventional and widely deployed "pulse" radars; the concept is tightly coupled to a small satellite bus / deployment philosophy.
5	Large Deployable Antenna/reflector	The Large Deployable Antenna is a large size payload that would demand a dedicated IOD mission. European non dependence in terms of Large Reflector Technologies has been promoted also by ESA. Usage of the boom and LDA system could be commercial and applicable to a wide range of satellites (including constellation-based services) and applications thanks to its scalability.
6	Electronic-signals Intelligence	An ELINT (ELectronic-signals INTelligence) mission based on the Frequency Monitoring Payload could be a dedicated mission or a hosted payload on a small satellite.The technology could be of interest for ITU compliance and protection of space assets from ground based radio frequency interferences, even for GEO. It could be of interest for cybersecurity topics: potential customers could be the governments and defence organisations from EC countries.
7	GTO IOD Mission	This mission concept aims at putting on a GTO orbit a platform carrying a set of IODs that could benefit from a recurrent passage through the Van Allen Belts with long lasting exposure to radiation environment. The mission can be of particular interest for studying effect of radiation on the electronics and correlating them to occurrence of errors. Moreover the mission can be suitable for testing novel error detection methods as well as self-healing hardware.

 © GMV 2016; all rights reserved

#	Mission Name	IOD/IOV Concept and Objectives
8	GNSS Reflectometry	A dedicated mission to demonstrate techniques and technologies related to GNSS reflectometry could be of high interest for institutions and for the potential applications for the community. The promotion of the technology is important for gaining competitiveness wrt similar USA an NASA programmes.
9	ISS experiment	ISS in the frame of IOD/IOV can be considered for hosting an experiment to be performed on-board the Station with collaboration of astronauts (in the inner volume or exposed outside the station)
10	Electric Propulsion On-Orbit Test Bench	The idea is to develop a (or adapt an existing) carrier designed to host, on recursive base, with successive launches, innovative Electric Propulsion systems or components/parts of them needing in-orbit demonstration/validation as main IOD payload. The baseline carrier should be provided with a flexible/modular power generation system to be tailored on the basis of the power needs from the Electric System (modular solar arrays configuration, modular battery/accumulation system).
11	Hyperspectral Remote Sensing	Hyperspectral instruments are missing elements in Europe. Thus a gap should be filled once PROBA-1 mission will end is life. The main interest in demonstrating this technology could be institutional (ESA, EC with Copernicus programme). The services and applications potentially enabled by these technologies can be commercial: agriculture (crop monitoring), ocean monitoring (contamination), mining (surface analysis) and disaster management (analysis of natural or unnatural disasters) aside from potential scientific applications
12	VEGA as IOD carrier	Usage of VEGA modified payload adapter for conducting experiments. Maximum exploitation of a European launch vehicle like VEGA for IOD purposes would be desirable both for institution, launcher developer and provider as well as for technology owners.
13	GEO Hosted Payload IOD	The main objective of an IOD in GEO can be the demonstration of telecommunications related technologies. The demonstration could take place at different level of integration in the hosting spacecraft system.

When analysing which mission options should be made available to a customer of an IOD service (top-down approach), 6 different options have been identified, which combine the possibility of flying a technology alone or in collaboration with other IODs, the redundancy options and the qualification level of the components of the platform.

Analysing all the data, and taking as well into account lessons learned from previous IOD initiatives (PROBA, TET, TechDemoSat, EuroIOD..), it is possible to conclude that an IOD service mission portfolio should be formed by two different types of mission:

1. Institutional IOD missions that require carriers with IOD payloads in the range of 50 Kg. This range of payload allows achieving complex missions and demonstrating new techniques in orbit, which can even be precursor of future scientific and exploration missions or new space-based services. In these mission, a central IOD payload defines the overall mission, other companion technologies (for instance, up to 10) can also be flown. In this mission, the complexity and cost of the primary payload justifies the size of the spacecraft and the fact that the mission is not built integrating “black boxes” experiments. The client of this type of mission would be institutional, with the potential of having some commercial clients to fill up the capacity of the satellite.
   These missions are similar (in terms of size and purpose) to previous IOD institutional programs like PROBA.
2. Small IOD missions where only few (for instance, up to 3) compatible IOD technologies are flown or tested. The sum of the payloads should be in the region of 10 Kg of payload. If possible, cubesat based platforms should be used to reduce costs. The clients of this type mission could be mostly private (commercial) users, institutions could join as well but this time they would not be the primary user.

© GMV 2016; all rights reserved

5.4. IOD SERVICE USE CASES

Among the different missions that could be offered by an IOD service two use cases have been selected. Those have been analysed more in depth in order to identify their implementation costs and schedule, and therefore further refine our definition of IOD service. The following use cases have been selected:

- Use case A is a mission with an institutional client, interested in demonstrating in orbit a payload of around 50kgs, which can be the precursor of a future service. Based on the mission concepts identified by IODISPLay previously, the Space-based Debris/NEO Observation and Identification payload has been selected. Around this payload, other additional IOD experiments of opportunity (to be sold commercially, potentially) have also been identified.
- Use case B is representative of the situation where commercial customers come to the IOD service provider with a number of different technologies, to which an IOD opportunity must be offered at competitive price. For this, a handful of interesting technologies from the database have been selected, taking into account their potential commercial viability and hence the willingness to pay from the customer, as well as the potential of these technologies of being instrumental in New Space applications.

Note that both use cases have been selected because of their representativeness with respect to the IOD service scheme that IODISPLay has identified and preliminarily outlined. It is important to underline that this does not discard the applicability of other mission concepts or technologies to the IOD service, nor such use case selection is meant to give more importance to one technology with respect to any other one.

A preliminary mission design of each of these use cases has been carried out, which has also helped to identify with concrete examples the costs, the needed elements and the implementation schedule needed by a mission that should be implemented by the service.

5.5. THE BUSINESS PLAN OF AN IOD/IOV SERVICE

Based on the preliminary design of the use cases, and on an estimation of the effort needed to offer all the elements of the IOD service, a business plan has been prepared. The following paragraphs provide the estimation approach for the revenues and costs of each service.

5.5.1.1. Revenues Estimation

The revenues estimation is based on the application of three different approaches, described below.

- **Mark-up on operational costs:** this approach is based on the application of an assumed percentage mark-up on the amount of total operational costs sustained by the IOD service in order to provide the service. This approach has been applied with reference to the following services:
  - Technology Intelligence[1];
  - Feasibility studies;
  - Mission implementation, with reference to the so-called "Small Missions"

  This approach ensures, by the definition, the economic sustainability of the business units engaged in the provision of the services mentioned above. In this respect we decided to maintain the most competitive mark-up, and the upper limit has been set to 7%, in consistency with to the current agreements in force between the European Commission and the consortium partners.
- **Success fee:** this approach consists in applying a percentage fee on different economic basis (e.g. costs, indemnification deriving from lawsuits, estimated economic benefits of various nature, etc.) in case a pre-determined event occurs. With reference to the IOD commercial service, this approach has been used for to the following services:
  - Matchmaking of IOD opportunities, in case a successful match is provided. The success fee is calculated on the basis of the average total mission cost, as identified by the consortium partners;

[1] It is necessary to note that the revenues of this service derive from a long term procurement with EC, therefore the service is operational through institutional funding.

 © GMV 2016; all rights reserved

 - Matchmaking of investment opportunities, in case a successful match is provided. The success fee is calculated on the basis of the amount of the average amount of external funding provided by financial partners in order to cover the average total mission costs.

- **Institutional funding:** when the business unit's revenue model is not capable of ensuring the complete financial viability, it has been assumed that the costs that could not be covered by the "commercial" revenues generated by the service will be covered – totally or partially – through institutional funding. This approach has been applied with reference to the following services
  - IOD Technology intelligence: the revenues of this service are represented by a long term procurement with the European Commission. It is assumed that the agreement will include a 7% mark-up on total operational costs;
  - Mission implementation: this service is assumed to be partially financed through institutional funding. In particular, small commercial missions are assumed to be partially funded in the initial period of provision of the services, with the final objective of becoming financially autonomous in the medium term. On the other hand, large institutional mission are assumed to be fully financed for the entire considered timeframe, with the objective of becoming partially commercial in the long term (e.g. offer hosted payload to third parties).

5.5.1.2. Costs Estimation

The operational costs related to the provision of the Strategy Office and Mission Implementation Office have been determined with reference to two different macro-categories:

- **Direct Costs:** they represent all the costs related to the core activities strictly required in order to guarantee the service provision, including the total salaries of the professionals that compose the team dedicated to each service, and – for the mission implementation services – other operational costs that refers to the platform, launch and ground segment services. It is necessary to underline that the total salaries are weighted for the actual effort estimation in terms of man/month for all the core activity of each service, thus they represent a fraction of the total monthly salaries of the professionals included in the different teams.
- **Overhead:** the overhead costs represent all the so-called "indirect costs". These are all the costs that the service provider has to sustain in order to be fully operational. Nevertheless they are not related to the core activities required to provide the different services (e.g. IT, Human Resources, Finance & Control, Marketing, etc.) and the costs of running an office (e.g. utilities, computers, telephone, etc.) It is important to note that the actual effort – and thus costs – of the marketing activities, that should be included in the overhead costs, has been estimated precisely with the same approach adopted for the direct costs.

5.5.1.3. Evaluation of the business plan

The analysis carried out with the business plan showed that the IOD service is not able to reach full economic autonomy during the considered timeframe. The main outcomes of the business plan are detailed below with reference to each service:

- **IOD Technology Intelligence**: this service is expected to be able to self-finance within the business plan timeframe. This is due to the selected revenue model, which consists in the application of a fixed mark-up on operational costs. This business unit is therefore expected to generate every year around 300-350 thousand Euros of revenues and around 20 thousand euros of margin;
- **Matchmaking of IOD opportunities**: this service is expected to be able to progressively self-finance thanks to the revenues generated through the success-fee revenue model. When the business unit will be fully operational (e.g. 6 successful matches are provided every year), it is expected to generate around 250 thousand Euros of revenues and around 60 thousand euros of margin. It is important to note that the average price for the client for a successful match is around 40 thousand euros, which can be considered a fair and competitive compensation for this type of service;
- **Matchmaking of investment opportunities:** the economic results of this business unit show a structural condition of operational losses during the entire timeframe. This situation is due to the fact that – even if the cost structure is reasonably "light" – a higher number of successful matches is needed in order to reach at least the break-even point. The business

 © GMV 2016; all rights reserved

unit is therefore expected to generate every year around 20 thousand Euros of revenues and around 80-100 thousand euros of operational loss. It is important to note that the actual demand for this type of service should be further verified, since the interest and availability of investment funds to provide financial resources to the DIO service clients is not guaranteed. This is a consequence of the "standard" characteristics of typical investment strategy of these subjects, such as the investment period and the expected return on investment, which may conflict with the development timeframe and commercial exploitation of the technology of the IOD services' clients.

- **Feasibility Studies**: this service is assumed to operate under a mark-up scheme, thus the financial viability is ensured by definition. The business unit is expected to generate around 300 thousand Euros of revenues and around 20 thousand Euros of margin. The average price of a feasibility study will be of around 280-300 thousand Euros, which can be considered a fair and competitive compensation for this type of service;
- **Mission implementation**: the mission implementation service is partially self-financing. In particular the commercial revenues will be generated only through the small private missions, while large institutional missions are assumed to be fully funded by the EC during the entire business plan timeframe. The revenues of the business unit range from 6 to 10M Euros per year, on the basis of the mission implementation cycle (e.g. initial setup of the mission implies higher costs and thus higher revenues), and the margin ranges from around 400 to 650 thousand Euros. The mixed revenue model (mark-up on operational costs plus institutional funding) allows the IOD service to offer an initial ticket for space price (small missions) of around 300 thousand euros per Kg that will increase to around 470 thousand euros per Kg when the service will be fully commercial. With reference to the institutional missions, the average price per kg paid through institutional funding ranges from around 300 to 400 thousand euros per kg. The figures of both the two types of mission may be considered as fair and competitive.

Finally, it is important to report that the choice of a mixed revenue model including both commercial revenues and institutional funding is supported by the results of the data gathered during our market analysis. In fact, the comparison of the availability to pay with the budget for IOD commercial missions estimated in IODISPLAY reveals that current availability to pay is insufficient to cover overall mission costs. This gap could be filled through different solutions:

- Some of the interviewed companies are potentially interested in accessing financial solutions to loan the required resources;
- An institutional player could cover the costs that cannot be covered by the demand, as it is assumed for the mission implementation service.

With respect to this last point, the external contribution required for the service is foreseen to decrease through the time, as an effect of the following trends: a) economies of experience and scale generated by the provider of the service through the time, leading to a reduction of IOD mission costs and b) increased willingness to pay by technology developers through the time, driven by the profits generated by technologies demonstrated thanks to the service, as well as by a change of mentality with regards to IOD due to the existence of the service itself.

5.6. SETUP OF AN IOD SERVICE

As clearly shown by the performed IOD market analysis and, more in detail, from the business plan, at the moment an IOD service could not be profitable or self-sustained. Nonetheless, the benefits that such service would provide to the European space arena have also been identified, offering IOD opportunities that will be:

- Predictable, allowing planning and set aside IOD resources in the development roadmap of a new technology;
- Frequent, maximising opportunities for flying technologies (1-2 per year as goal)
- Affordable, as limited resources impose that an IOD service can become a reality only if available at low cost, justifying investment in demonstration flights from technology developers

 © GMV 2016; all rights reserved

Also, the European Commission has manifested, through issuing the COMPET-05-2014 call, that there is a public interest in solving the current IOD/IOV situation, as it stated that "[…] The challenge in H2020 is to make access to space possible for new technologies and innovations by means of in-orbit demonstrations (IOD) and/or validations (IOV).[…]".

Such challenge could be faced by offering H2020 support to the setup of the IOD service, which can take form in the following ways:

- Ensuring an anchoring client to the IOD service, such as being the client for the IOD office and profit from its services
- Offer in-kind elements to the implementation of the IOD missions such as, for instance, the provision of a European launcher
- Providing financial support to the setup of the IOD service such as financing the implementation of pilot missions

The financial support of the H2020 to the IOD service will have the goals of ensuring that the elements provided by the IOD service can be implemented and of stimulating the commercial market in order to aim at the financial self-sustainability of the IOD service.

Hence, the financial support should phase out with the time, as the IOD service relies more and more on commercial and private customers. This could be implemented by having a number of mission supported by H2020 with decreasing financial support, with at the same time an expected increase of the commercial payloads in these missions (while not excluding that the commission will be a customer of the IOD service itself). In such a way, the EC could also have the possibility to oversee how the IOD service is performing and if the market is being stimulated enough to enable the commercial viability of the service. In case this does not materialise, then the EC could limit or stop the financial support to the service, with the remaining result that a number of IOD technologies have anyway been flown and demonstrated in orbit. Moreover, the EC support would provide high visibility to the EC service initiative and therefore higher probability of market penetration.

Also, financing IOD missions through the IOD service would be an opportunity to select, among the technologies to be flown, elements that have been developed under the FP7/H2020 scheme and that have not yet had the opportunity to be demonstrated in orbit. The IOD payload selection, or the thematic of the IOD mission(s) to be implemented, could also be open to other themes such as supporting upcoming newspace applications by demonstrating enabling technologies, or further foster the European non-dependence effort already done at EC-ESA-EDA level by demonstrating critical technologies in orbit.

It is expected that the EC financial support could be given under H2020 competitiveness rules under a series of grants, either as Research and Innovation actions or Innovation Actions, depending on the level of funding required. This will ensure fair competition and potentially the emergence of more than one service provider.

As evidenced by the presented business plan, financing an institutional IOD mission could require a support from H2020 in the order of 25 M Euros in total: this can be considered substantially higher than typical H2020 space grants. Also, in FP7/H2020 activities which had in their program to have an IOD, sometimes had difficulties of actually performing it, thereby coming short in their initial objectives. This could be solved by having a technical supervision and support of the implementation of an IOD mission under H2020 umbrella by an external entity such as the European Space Agency.

An example of how the IOD service could be supported by H2020 is depicted in the following diagram, which shows that the IOD office could start after the publication of the first H2020 work program in 2017, thereby creating the basic infrastructure for a European IOD service. The IOD office, acting as a one stop shop for IOD activities, would also manage the subcontracting activities that will be carried out to implement IOD missions with H2020 financing. In order to avoid conflict of interests, the IOD office constituents will not be allowed to bid for the subcontracted activities, which will be amount to most of the institutional financing. At the same time, the ESA technical overview should start, in order to support the implementation of the missions.

 © GMV 2016; all rights reserved

In the following work programs a number of missions could be initiated, with a mix of institutional IOD missions (with IOD payload in the region of 50 Kg) and smaller IOD missions (with IOD payload below 10 Kg to be sold potentially in the commercial market).
It is expected that, for the IOD institutional missions, the support should decrease gradually, as with time IOD tickets will be sold around a central payload. It is assumed that the first institutional IOD mission will be financed in full by the institutions.
For small IOD missions, an initial support from the institutions would be needed in addition to the costs covered by IOD tickets sold to commercial clients. In this case, the objective is to go towards a fully commercially funded small mission.
Both types of mission would rely on a launch opportunity provided by the EC, as well as being overseen technically by ESA. The IOD office would enable having coherence among all the missions, as well as providing additional services (IOD intelligence, IOD opportunities matchmaking and investors matchmaking).

The roadmap also offers the possibility, after the 4 initial years, to evaluate if the market is responding to the public procurement of an IOD service and in the effect on the community of the missions that have been implemented until then. In addition, upon the completion of this phase and of the first missions, the institutions will be able to assess the benefits of performing IOD with this type of scheme.

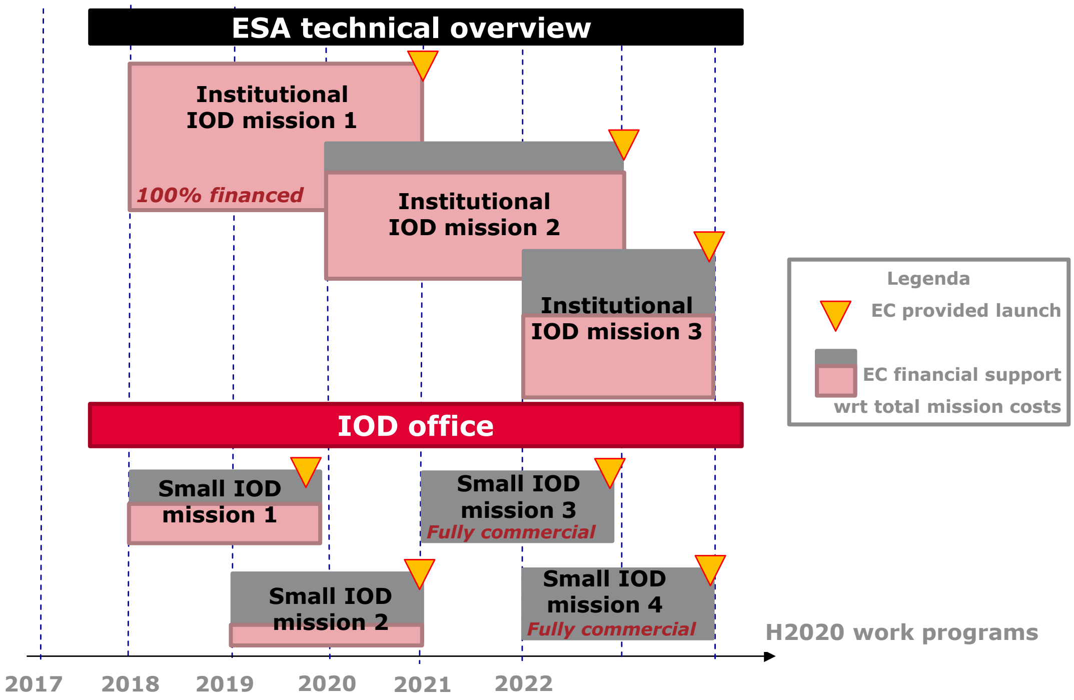

Figure 5-3: potential setup of IOD service elements under H2020 support

Concerning the financial support, based on the carried out estimations the following can be assumed:

- the IOD strategy office would require around 350-400 thousand Euros per year of EC contribution. Said amount represents the revenues of the IOD technology intelligence business unit within the assumed long term procurement agreement;
- an institutional IOD mission could be implemented with around 22M Euros of total EC contribution, provided over a 3 years timeframe, under the assumption of full funding of missions costs and contribution in kind of the launcher;
- a small IOD mission could be implemented with around 2M Euros of EC contribution over a 2 years timeframe, under the assumption of 50% funding of the costs of the first mission, with contribution in kind of the launcher, and no funding from the third mission onwards

These values are expected to decrease (up to 20/30% after the first missions or IOD service operations).

 © GMV 2016; all rights reserved

6. CONCLUSIONS

This document has described the results of the activities carried out in the frame of the H2020 IODISPLay project, whose objective is to identify a number of solutions for IOD/IOV of technologies within Europe.

During the project, a substantial amount of data on the technologies that would profit from IOD/IOV, as well as the carriers and launchers that would bring them to orbit, has been obtained and structured in the database.

This has once more validated the existence of the "valley of death" of the TRL, as well as a need of shift of paradigm if the situation is to be changed.

One results has been that within the current situation most of those technologies would not find their way to flight. As consequence within IODISPLay concept of an IOD service scheme has been proposed and preliminarily outlined. This need was also in line with the main messages gathered during the IOD workshop held in November 2015, which highlighted the need of fostering a scheme for providing frequent and ideally self-sustainable access to space.

The scheme foreseen by IODISPLAY is based on a European IOD commercial service, where an entity would act as a single stop shop for all actors interested in an IOD/IOV, as well as subcontract all the main activities needed to implement an IOD mission.

The service objective would be able to provide predictable, frequent and affordable access to space.

The IOD service would also provide IOD intelligence and flight opportunities or investors matchmaking. The target missions for such service would basically be two: a first type of mission with a main institutional IOD/IOV payload (in the region of 50 Kg), completed by other IOD slots that could be offered commercially; and a second much smaller type of mission (with a total IOD/IOV payload in the range of 10kgs), that would be fully commercial.

The market analysis and a business plan review of the IOD service show that this entity could not be, at present, financially self-sustained. Since the benefits it would bring for the community would be real and would allow changing the current IOD situation, it is proposed that institutions should support the emergence of such IOD service scheme. The objective of the public support would be not only to finance the first steps of an IOD service, but also to stimulate the market so that it could provide commercial income and eventually profitability to the IOD service providers.

In this document, a potential way of supporting the emergence of an IOD service through H2020 space resources has been proposed, which includes the implementation of a number of IOD missions as well as the support from an external technical expert like ESA, which would provide high confidence in the outcome of the program.

© GMV 2016; all rights reserved

END OF DOCUMENT

© GMV 2016; all rights reserved