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ABSTRACT

This document is the Executive Summary of the ESA study "IOD of techniques and technologies for M2M Telecom missions".

Generally speaking DIAMS has been an opportunity to secure the feasibility of the IOD in technical, programmatic and financial terms. More specifically DIAMS has allowed to define the end-to-end mission concept for this IOD, covering the design of various associated segments : Space Segment (Payload, Platform), and Ground Segment. Both interest and programmatic aspects have also been consolidated.

- On the technical plane :
  Both the requirements and the design of the system have been refined to validate the IOD concept :
  - The M2M communication elements have been designed to match the disruptive service requirements (integration with terrestrial, low cost/power terminal).
  - The IOD space segment, the mission, and the operations have also been studied. The accommodation of the relevant M2M payload on the PROBA-NEXT platform has been validated: top-floor payload antennae accommodation, power/mass budgets, communications, etc. Moreover, we have shown that the spacecraft design brings comfortable flexibility in terms of orbit choice (different LTAN is possible), which is a key asset for increasing the range of launch opportunities (dual launch possible on Vega launcher).
- On the programmatic plane :

  Based on the mission designed, the IOD programmatics has been elaborated, including development plan and industrial organisation, from B1 to E2 phase. The development and validation approach follows the ESA standards, in terms of phasing, and review milestones. The schedule is consolidated, taking into account the concurrent existing development activities (PROBA-NEXT or M2M system roadmaps). The ROM cost, and the whole schedule are compatible with the IOD ESA constraints, pending any launch opportunity.

The work described in this report was done under ESA contract. Responsibility for the contents resides in the author(s) or organisation(s) that prepared it.

Names of authors

Fabrice PLANCHOU AIRBUS DEFENCE & SPACE

NAME OF ESA STUDY MANAGER: Juan LIZARRAGA DIRECTORATE: Telecommunication and Integrated Applications (TIA)	ESA BUDGET HEADING GSP

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ESA CONTRACT No. 4000110351

IOD OF TECHNIQUES AND TECHNOLOGIES FOR M2M TELECOM MISSIONS

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EXECUTIVE SUMMARY

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Authors Names:	Fabrice PLANCHOU (AIRBUS DEFENCE & SPACE)
ESA Study Manager:	Juan LIZARRAGA, ESTEC

with support from

1 M2M SATELLITE SYSTEM

1.1 IOD FOR THE IOT

Internet-Of-Things (IOT) and Machine-To-Machine (M2M) communications have a very large potential market growth, particularly in the low-cost, low data rate segment. However, current satellite systems are not adequate to serve very large populations of small mobile terminals with low bit rate requirements and severe cost and energy constraints. To this purpose Airbus DS is developing an internal initiative aimed to build a M2M satellite system which consists in a hybrid constellation of LEO-GEO satellites. The LEO satellite architecture is based on innovative concepts and technologies, some of them taking benefit from synergies with emerging terrestrial M2M technologies e.g. ultra-narrow band (UNB) air interface.

The targeted innovative technologies and techniques bring new opportunities of applications for the satellite by increasing performances and reducing drastically the costs of the terminals and of the services for the end users.

Derisking these innovations is essential in order to guarantee the possibilities and performances of the system before investing larger funds needed for its full deployment. From this perspective, DIAMS was an opportunity to establish the technical and programmatic roadmap of an IOD mission that would validate the necessary set of technologies, techniques and system concepts.

1.2 HYBRID SYSTEM CONCEPT

The overall system is from the start designed to offer a coherent integrated LEO satellite/terrestrial cellular M2M Low Data Rate service as shown on the Figure 1-1. When possible, the user will communicate through the terrestrial cellular network. Some of the terrestrial cells that are isolated may be linked to the backbone through a broadband satellite connection. Outside the terrestrial coverage, the terminal switch transparently in satellite mode and send its messages through the LEO satellite system. The quality of service provided by the satellite system and the terrestrial system are as close as possible.

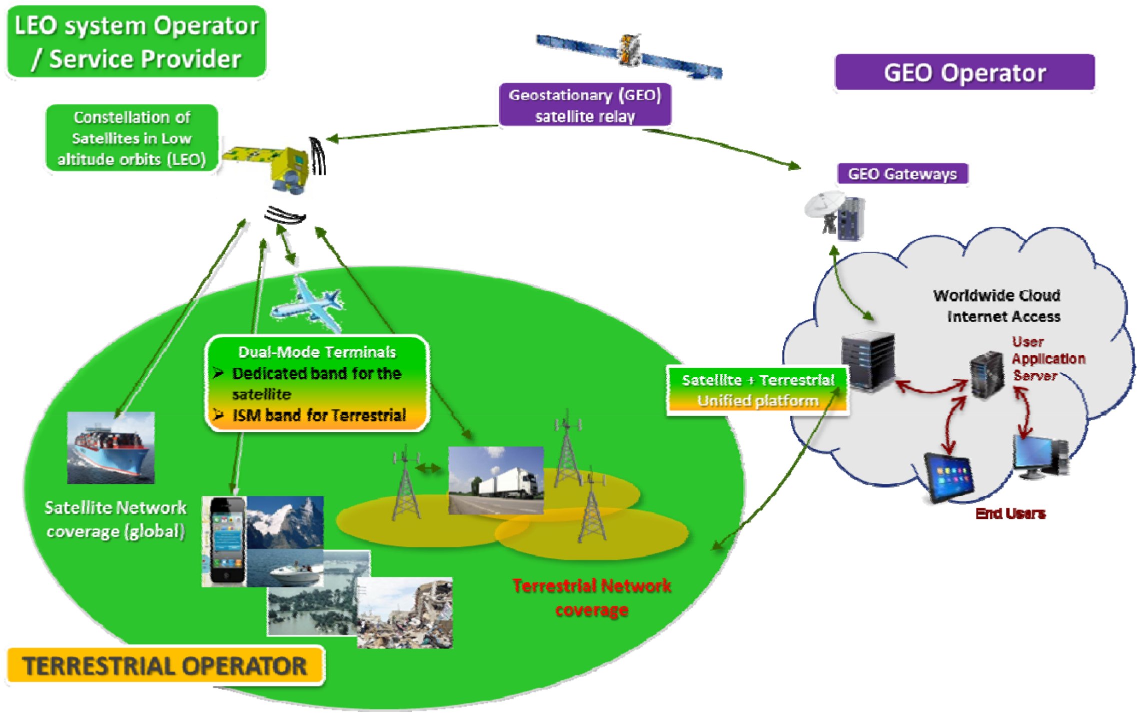

Figure 1-1 : Integrated Satellite/Terrestrial LDR M2M System

One of the key driver identified for satellite M2M systems is the integration with terrestrial technologies. In the targeted system, the modem device is natively dual mode. Each communication mode offers the same service class (message size, size/cost/energy consumption of the terminal). Ideally, a single identification module is used for both modes.

In existing satellite/terrestrial solutions, the integration level is very loose, and force the users to have 2 contracts (that can be packaged) and with a terminal that aggregates 2 heterogeneous modems that are integrated at the application level only. The modems devices (GSM for the terrestrial, Iridium/Orbcomm/Inmarsat for the satellite) therefore are not homogeneous in size, cost and energy consumption.

2 DIAMS ORGANISATION

The study logic adopted for this study reflects the set of tasks defined in the ESA Statement of Work. The different elements and subtasks of the study logic are detailed in Figure 2-1, which is also highliting the contribution of each partner within DIAMS.

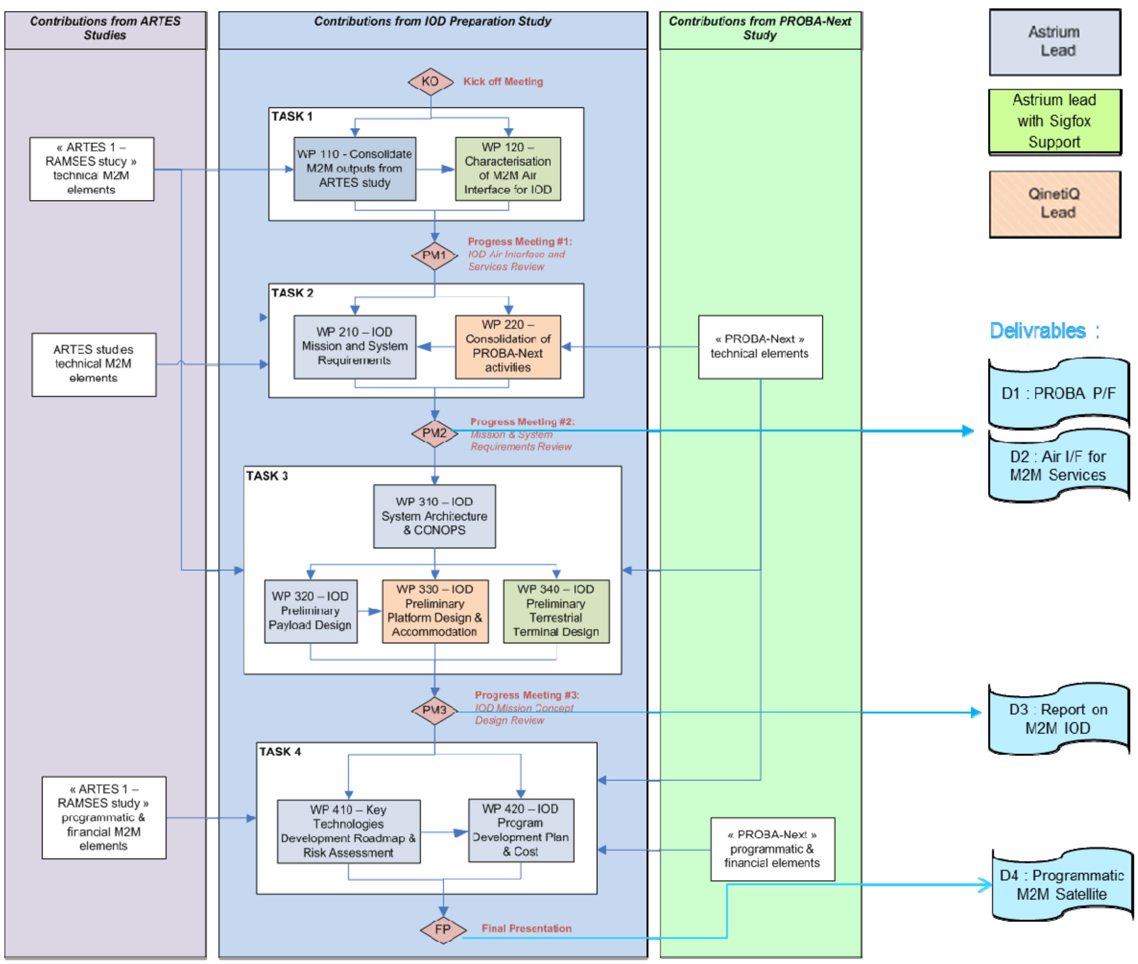

Figure 2-1 : Study Logic

3 IOD MISSION

3.1 MISSION OVERVIEW

IOD mission is intended to be embedded within the M2M hybrid system, and more specifically as part of the whole satellite access network (constellation) for M2M services.

The proposed IOD mission will :

1. Take part to the M2M satellite service promotion / ramp-up : the IOD could act as a precursor mission within the future M2M hybrid system
2. Contribute to the final service, as another LEO satellite part of the targeted constellation

The first crucial objective is the **user air interface** on which we want to focus the IOD mission.

The air-interface is the most challenging element within the M2M satellite system. Both the terminal and the LEO satellite (on-board signal processor) end-points are concerned.

It allows to demonstrate some services by connecting the M2M prototype terminals to the peer applications, through the LEO satellite system.

It is expected to confirm and demonstrate the feasibility of the service, and to validate key technical challenges that are inherent to the M2M by satellite concept. The IOD system is designed to be compatible with the M2M system mission. The only difference is in its implementation, since we propose to get rid of the LEO-GEO relay and to use a **"LEO direct-to-ground" interface** to interconnect the M2M terminals to the service platforms..

The idea is to minimise the mission constraints, especially with regards to the regulatory aspects attached to the geostationary interface. This also simplifies the satellite design (cost) and the operation set-up, since only LEO ground stations would be necessary, to connect the M2M back-end.

3.2 OPERATIONS

For the IOD satellite operations, the best option is to rely on ESA REDU ground station (Belgium) for the satellite mission and control centre. This centre is already operational for various ESA IOD mission and fully equipped with the convenient means : TT&C antennas, SCC platforms, and in particular those developed by QinetiQ Space, based on the heritage of previous PROBA missions

From the mission point of view, the IOD operations will be coupled with both :

- M2M Network Operation Centre (NOC), for the whole M2M service management.
- Airbus DS / Sigfox lab's for the post-processing of ISM spectrum monitoring.

4 SPACE SYSTEM

4.1 PAYLOAD

In order to meet the low-cost./low-power requirement on the M2M user terminal, it is needed to implement on-board processing (de/modulation, signal/data processing) for an efficient air-interface. Airbus Defence & Space proposes a processed payload that will be customized for the M2M IOD mission. The design is divided into 2 main blocks:

- 1 RF Frontend from/to the Earth, including 4 antennas with their own LNA and one shared SSPA
- 1 Processing Module composed of a conversion stage with down-converters, ADC's, mixers and DAC's, and a processing block

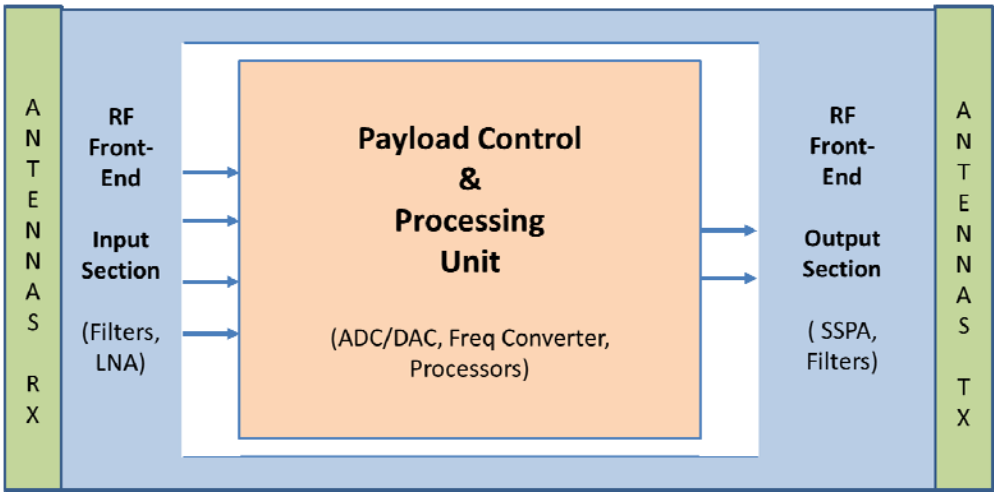

Figure 4-1 : DIAMS Payload Overview

The key element of this Payload is the PCPU, which is currently developed by Airbus Defence and Space developed and supported by ESA (contract reference: 4000116208/15/NL/US).

The architecture has been defined to serve several applications, with at least 5 flexible RF inputs, capability by design to process at least 14 MHz bandwidth (typically 600 KHz needed for the M2M system) within this input range, processing by re-programmable FPGAs coupled to processors, and 5 corresponding flexible RF outputs.

It has been designed to be cost effective and minimize mass / volume / power, making use of advanced components, like flexible RF front-ends / converters, intended to be qualified for space use.

4.2 PLATFORM ACCOMMODATION OVERVIEW

The main objective of this study was to investigate the feasibility of using the Proba-Next platform for the accommodation of the IOD payload and the in orbit demonstration of advanced telecom operations. Key challenges were identified as being the payload power consumption and the accommodation of the payload antennae on top of the PROBA-NEXT bus.

The study has been done on the basis of the specifications elaborated within DIAMS the study : M2M constellation, orbits, launch constraints, and the satellite payload.

DIAMS payload includes three antenna types and four electronic units. Two L-band (T2 type) antennas will be placed on the nadir panel (payload panel), facing the earth and deployed under a 50 degrees angle with respect to the nadir direction. One L-band (T1 type) antenna and one UHV (T3 type) antenna needs to be accommodated on the nadir panel. Figure 4-2 shows an example of the payload antennas accommodation on the PROBA-

NEXT bus and gives an overview of the size and shape of the antennas. The payload mass shall be 21kg at maximum and shall consume 55W, both without any margins.

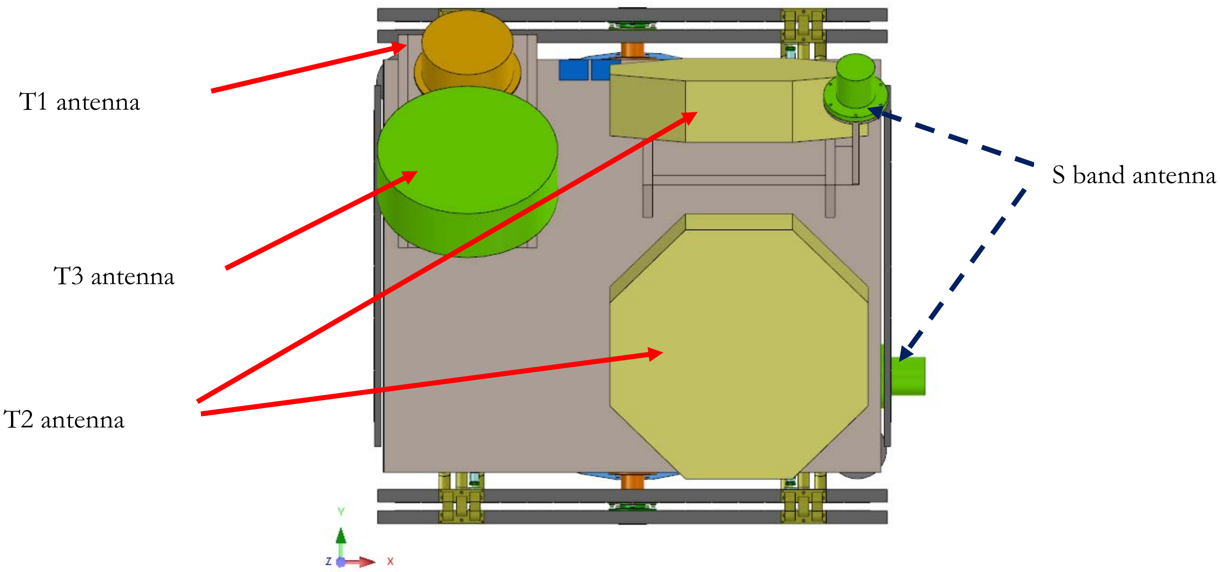

Figure 4-2 Payload antennas accommodation on nadir panel (payload panel). External bus units are marked with dashed arrows.

The main accommodation conclusions are:

- The mission is feasible in terms of power consumption and the platform design allows for the flexibility to choose an orbit with a different LTAN.
- It is possible to accommodate the payload antennae on top of the Proba-Next bus and no major conflicts are identified.
- Two spacecraft fit inside the dual launch volume of the Vega launcher.
  This allows for a dual launch and deployment of a constellation of two satellites.

The main system characteristics are summarized in Table 4-1.

Table 4-1 Summary of main system characteristics

Orbit	SSO at 680 km, LTAN of 10:30hr
Power consumption during nominal mode	136W incl. margins
Power consumption during S-band communication	167W incl. margins
Required number of solar strings	36 (4 deployable and 2 body-fixed solar panels)
Solar cells per string	18
Solar cell type	Azur Space 3G30
Required battery capacity	18Ah
Attitude control hardware	4 reaction wheels in tetrahedral configuration 3 magnetotorquers with internal redundancy
Attitude determination hardware	2 earth sensors and 1 magnetometer (plus a complete redundant set)
Position determination hardware	GPS
Propulsion	1+1 1N MONARC-1 thruster with 12 kg propellant mass
Payload S-band downlink capabilities	16.8Gb/day using only Kiruna as the ground station
Total spacecraft mass (bus+payload+propellant)	184kg excl. margins and 252 incl. margins
Total delta V capability	109 m/s
Gross volume (bus + payload + stowed)	1220x800x800mm^3

5 IOD PROGRAMMATICS

The IOD mission will be supported by:

1. One Space Segment composed of a LEO satellite equipped with the IOD payload.
2. One Ground Segment including satellite mission and control, and M2M user segment
3. Some system ground support equipment, used for training, or test and validation.
4. One Launch Service (configuration TBD) compliant with the programmatic scenarios and enabling to set-up a full system operational as quick as possible.

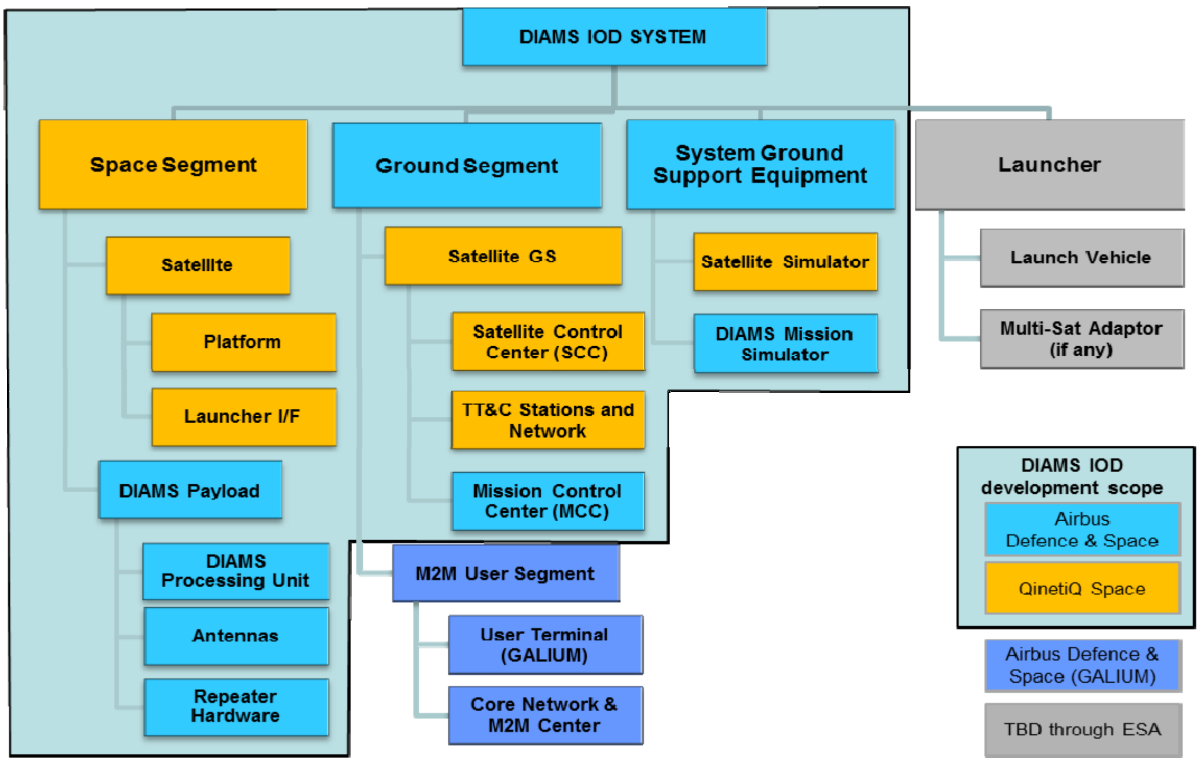

Figure 5-1 : Product tree for the IOD system development

Thnaks the work accomplished in DIAMS study, we consider that the maturity level of a phase A has been reached. Consequently the proposed IOD will start at the B1 level and will be conducted through five major phases :

1. **Phase B1**, aimed to freeze the IOD system concept (final system baseline) and confirm/derive the sub-system needs.
2. **Phase B2**, to detail the sub-system and provide the requirement documents
3. **Phase C/D**, to achieve the various development (and procurement), validate the subsystems, assemble and qualify the whole system(before launch).
4. **Phase E1**, to prepare & launch the satellite, execute the LEOP and the in-orbit commissioning
5. **Phase E2,** the operational phase, the IOD demonstration.

The Figure 5-2 illustrates the whole logic, from B1 phase to E2, as well as the main typical reviews which are scheduled along this such IOD.

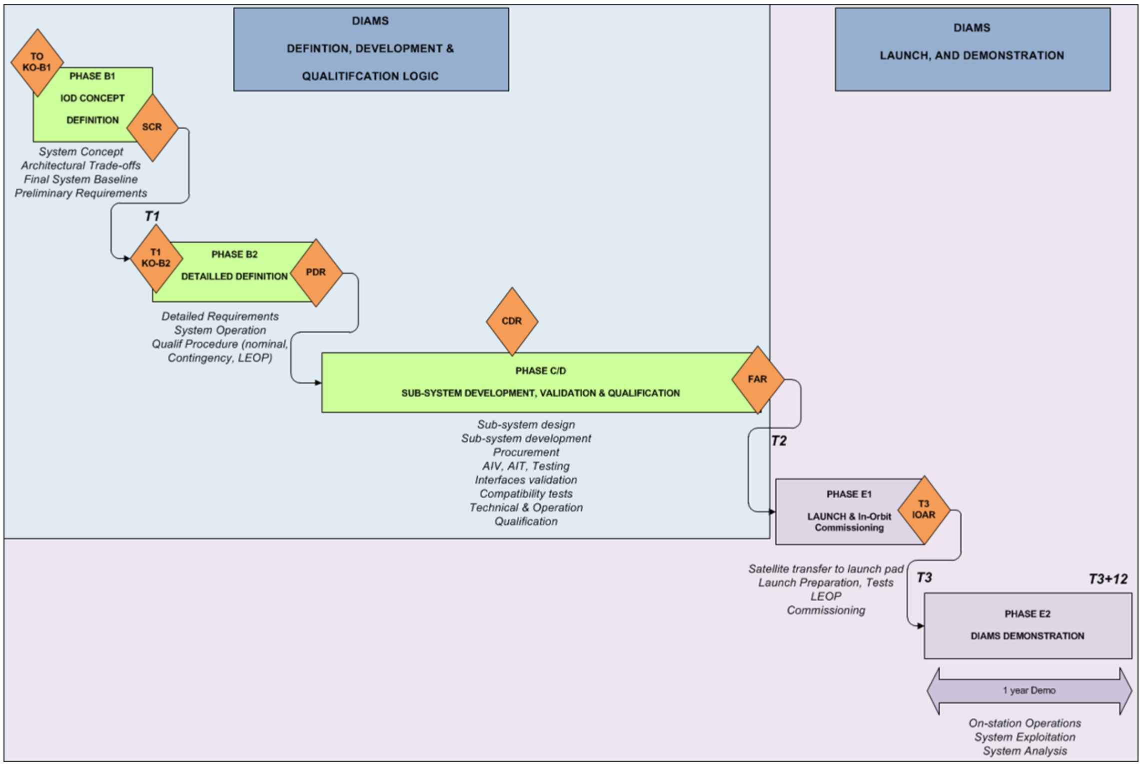

Figure 5-2 : DIAMS IOD Logic

6 CONCLUSIONS

DIAMS study has allowed to demonstrate both the interests and the feasibility of an IOD for the M2M hybrid system.

- On the technical plane :

  Both the requirements and the design of the system have been refined to validate the IOD concept :
  - The M2M communication elements (terminal, air interface, satellite payload) have been designed to match the disruptive service requirements (integration with terrestrial, low cost/power terminal).
  - The IOD space segment, the mission, and the operations have also been studied. The accommodation of the relevant M2M payload on the PROBA-NEXT platform has been validated: top-floor payload antennae accommodation, power/mass budgets, communications, etc. Moreover, we have shown that the spacecraft design brings comfortable flexibility in terms of orbit choice (different LTAN is possible), which is a key asset for increasing the range of launch opportunities (dual launch possible on Vega launcher).

- On the programmatic plane :

  Based on the mission designed, the IOD programmatics has been elaborated, including development plan and industrial organisation, from B1 to E2 phase. The development and validation approach follows the ESA standards, in terms of phasing, and review milestones. The schedule is consolidated, taking into account the concurrent existing development activities (PROBA-NEXT or M2M system roadmaps). The ROM cost, and the whole schedule are compatible with the IOD ESA constraints, pending any launch opportunity