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Availability analysis of a constellation with Petri nets based on deployment and renewal scenarios

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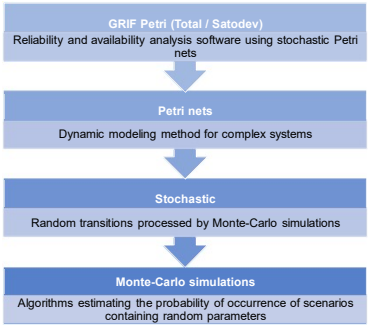
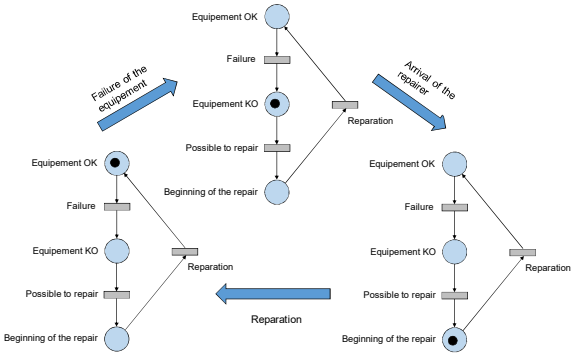
Introduction

- This poster analyzes deployment scenarios of a GNSS augmentation constellation project in order to characterize the impacts of the working hypotheses – including the type and number of satellites, the in-orbit stock management, the reliability of the satellites and launchers – on the expected performances and costs of the system.
- It presents the simulation approach using Petri nets – that is a mathematical and graphical tool for modeling and verifying the dynamic behavior of discrete event systems – combined with Monte-Carlo simulation, to optimize the performances of the deployment and renewal of this satellite constellation.

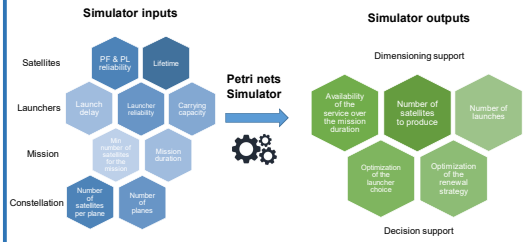
1. Petri nets concept



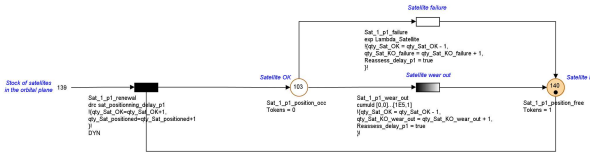


2. Satellite constellation deployment and renewal simulator

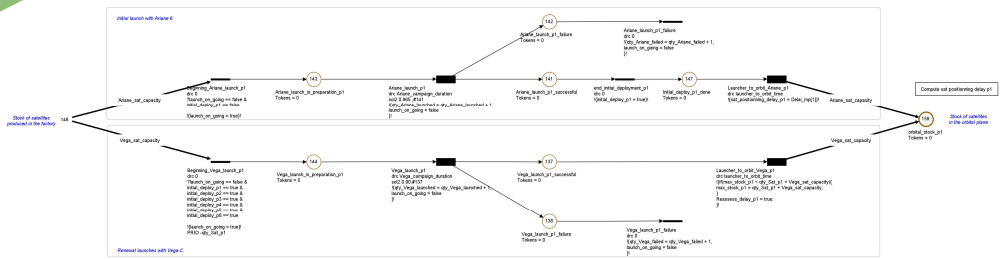
Principle of the simulator



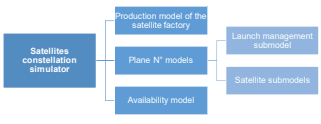
Satellite submodel example



Launch management submodel example



Structure of the simulator



3. GNSS constellation application

Scenarios	Inputs				Results			
	Satellites at initial launch	Vega-C launch delay	Redundancy in the constellation	Satellite reliability [FIT]	Constellation availability	Launched satellites	Launched Ariane 6	Launched Vega C
Reference	27	4 months	No	11 500	56.2%	450.1	6.2	40.3
				7500	85.7%			
First variant	32	4 months	No	11 500	81.6%	471.1	6.2	38.9
				7500	92.0%			
Second variant	27	2 months	No	11 500	91.3%	726.5	6.2	79.8
				7500	93.3%			
Third variant	27	3 months	No	11 500	88.2%	586.7	6.2	52.8
				7500	92.6%			
Fourth variant	27	3 months	Active 22/23	11 500	96.2%	586.7	6.2	52.8
				7500	98.3%			

Optimization of the availability
- Initial deployment strategy: number of spares
- Renewal strategy: launch frequency
- Architecture of the plane: active redundancy of satellites

Conclusion

- During the project phase 0, this simulation model allows a comparison of performances and costs between several envisaged scenarios and an optimization of the constellation regarding parameters as the number of spares, the management of in-orbit stock, the renewal strategy, …
- Depending on the technical and technological choices that will be made at the end of this phase, it will be possible to refine the working hypotheses taken within the framework of this study and to precise the trends that are emerging.