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iDREAM 2.0: A Paradigm Shifts Towards Reusable Space Systems

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Abstract. The design of next-generation flight vehicles for space access and in-orbit operations requires agile and modular tools that can support the rapid prototyping of expendable and reusable vehicles. Since 2020, Politecnico di Torino has been developing the iDREAM methodology and toolset within the framework of the GSTP program under the supervision of the European Space Agency (ESA). In its initial iteration, iDREAM focused on two case studies: a Micro Launcher (ML) and a Human Landing System (HLS). The toolset is composed of three main modules to: (i) support conceptual design activities through ASTRID-H, (ii) enable early-stage assessment of economic viability via HyCost and, (iii) analyze technology sustainability through TRIS, the dedicated technology roadmapping module. Moreover, a unified and upgraded database, supported by an in-house developed Database Management Library, supports the operation of all modules within the integrated toolset. The ongoing second phase (iDREAM 2.0) marks a paradigm shift by extending the methodology to support reusable flight systems, including first and/or second stage vertical and/or horizontal landing launch vehicles (RLV), reusable re-entry vehicles (RREV), and hypersonic use cases and introducing a highly modular environment. A key innovation lies in the integration of reusable systems modelling within existing expendable-focused routines, reducing redundancy and maximizing tool adaptability. The adopted approach focuses on minimizing the number of routines required for design and analysis while maximizing the coverage of reusable configuration combinations. Following a detailed trade-off analysis, the final architecture includes six routines for ASTRID-H, three for HyCost, and a single unified routine for the technology roadmapping TRIS module. This paper presents the current status of the ongoing iDREAM 2.0 project, which is currently in the development phase and undergoing validation through a set of reference vehicles. These include reusable launch systems, with vertical and horizontal recovery, reusable re-entry capsules, and hypersonic vehicle, demonstrating the framework's versatility in supporting the design of future reusable space systems.

Introduction

The contemporary space sector faces compressed timelines, heterogeneous missions, and rising cost pressure. Early decisions must therefore couple performance, affordability, and technology maturity – yet these dimensions are still too often treated in separate loops. Multidisciplinary Design Optimization (MDO) enables fast, coupled performance trades, but mainstream practice rarely integrates cost and technology roadmapping in the same decision cycle [1]. Concurrent design teams demonstrate that time-boxed, integrated studies accelerate iteration and improve traceability, but economic and maturation analyses are typically handed off to downstream tools [2].

Within performance, high-fidelity mission/trajectory tools (e.g., ASTOS [3]) assess launcher and re-entry feasibility but are not designed to co-evolve with cost or roadmap logic in early trades. In parallel, cost estimation spans agency and commercial traditions – from TRANSCOST and NAFCOM [4] to subsystem-level CERs for small-launcher markets [5] – yet these models are seldom wired directly to the conceptual sizing variables that drive mass and configuration sensitivities. Subsystem-granular CERs and “theoretical first unit” logic are most useful when fed by design data rather than spreadsheets; classic systems texts (e.g., SMAD [6]) similarly argue for considering affordability from day one.

On the technology side, roadmapping aligns stakeholder needs, capabilities, and enabling technologies. Phaal et al. [7] frame it as a flexible planning method. Building on this literature and ESA practice, TRIS introduced a rational, systems-engineering process that prioritizes technologies, quantifies schedule/cost implications, and plans maturation activities – moving beyond purely expert-driven roadmaps [8].

What was missing was a single, modular environment that (a) makes design, cost, and roadmapping talk natively; (b) keeps stakeholder needs in the driver’s seat; and (c) preserves consistent data across loops. iDREAM 1.0 addressed this gap within ESA’s GSTP framework (with ASI support), unifying ASTRID-H (conceptual/preliminary design), HyCost (early life-cycle cost), and TRIS (technology roadmapping) on a shared HyDat database and in-house management library [9].

This paper presents iDREAM 2.0, which generalizes that baseline for reusability and hypersonic missions. The architecture embeds recovery and operations within the same loop as sizing, cost, and roadmaps, while minimizing routine duplication. Concretely, it consolidates six ASTRID-H routines, three reuse-aware HyCost flows, and a single unified TRIS routine, all backed by an upgraded HyDat for traceable, one-source-of-truth parameters and automatic exchange of mass, cost, and roadmap evidence.

The paper is organized as follows: §2 summarizes iDREAM 1.0; §3 details the iDREAM 2.0 architecture and reusable-system extensions; §4 concludes with key findings and future work.

iDREAM 1.0 toolset and capabilities

iDREAM 1.0 integrates three pillars – ASTRID-H for conceptual/preliminary design, HyCost for early life-cycle cost assessment, and TRIS for technology roadmapping – on top of a shared database (HyDat) and an in-house Database Management Library, as shown in Fig. 1. ASTRID-H extends a decade of multi-fidelity sizing research at Politecnico di Torino from aircraft into microlaunchers and lunar landers, retaining a structured workflow that supports both *“sizing from scratch”* and assessment of existing configurations. It exchanges mission analysis data with ASTOS to refine closure: preliminary sizing (mass, dimensions, aerodynamics, propulsion) is iterated with an internal mission design routine, then re-optimized in ASTOS, and reintegrated into ASTRID-H to sharpen propellant and payload allocation. The microlauncher workflow implements both a restricted staging algorithm for feasibility checks and an optimal Lagrange-multiplier staging

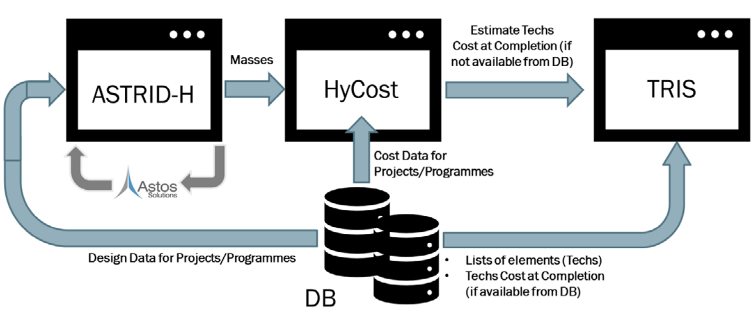

Fig. 1: iDREAM 1.0 structure.

scheme to minimize mass given payload and burnout velocity, with structural-ratio ranges linked to propellant type.

HyCost complements ASTRID-H by estimating development, manufacturing, and operating costs – as well as cost and price per flight – directly from design variables and performance outputs or from user databases. At its core are subsystem-level cost-estimation relationships, tuned with reduction factors for commercial applications and learning curve options for innovative manufacturing. The adopted approach builds on an ESA methodology for small and commercial launch vehicles based on *"recurring first unit"* logic and linear factors at subsystem/equipment level, extended in iDREAM to include process/manufacturing considerations so that estimates remain transparent and updateable as new commercial data emerge. HyCost also aggregates results by technology families to provide cost-at-completion inputs for TRIS.

TRIS closes the loop by converting the coupled design–cost view into a rational, stakeholder-driven roadmap. The methodology proceeds through five steps – (i) stakeholder analysis, (ii) elements definition (operational capabilities, technologies, building blocks, and mission concepts/activities), (iii) prioritization, (iv) planning, and (v) results evaluation – implemented with mathematical and logical models and supported by database-curated lists and resource estimates for TRL transitions. Recent updates improve allocation of budget/time in the planning algorithm and enable "non-ideal" roadmaps under constrained scenarios, reflecting ESA practice across hypersonic, re-entry, and exploration contexts.

These modules operate on a common data backbone. HyDat – a MySQL database originally developed with ESA to support technology roadmapping for hypersonic transportation and reusable access-to-space systems – now feeds and records parameters across design, cost, and roadmaps through a dedicated Database Management Library. The entire stack is implemented in Python with an integrated GUI; each module can be used stand-alone or in the fully coupled flow, ensuring traceable, bidirectional data exchange and repeatable studies.

With such structure, iDREAM 1.0 enables rapid *"what-if"* exploration where a design change immediately propagates to affordability and maturation plans – and vice versa. A validation on Rocket Lab's Electron [10] illustrates the approach: starting from public mission and configuration data, ASTRID-H/ASTOS converge on masses and dimensions within ~10% of reported values – consistent with conceptual-design expectations – while HyCost produces a subsystem breakdown aligned with reference costs and TRIS organizes a time- and budget-aware development path to TRL 9 over the program timeline. Methodologically, iDREAM sits alongside MDO/PIDO integration frameworks but takes a deliberately domain-opinionated stance: aerospace-specific routines and a shared database minimize setup friction and brittle file hand-offs while preserving the agility of early-phase trades. That foundation proved particularly useful as reusability became mainstream – where recovery constraints, refurbishment, and cadence-driven operations tightly couple trajectory, structures, and cost – setting the stage for the generalized, modular extensions presented in §3.

iDREAM 2.0 updated toolset and capabilities

iDREAM 2.0 generalizes the 1.0 framework to cover reusable systems and hypersonic use cases while deliberately minimizing the number of routines needed to span a wide configuration space. The guiding principle is to embed reuse logic inside the same expendable-focused workflows wherever possible, avoiding duplicate code paths and brittle hand-offs. After a trade-off on alternative decompositions, the architecture converged into six routines for ASTRID-H, three for HyCost, and a single, unified routine for TRIS. This structure keeps data consistent across modules and concentrates model complexity where it adds coverage rather than redundancy.

ASTRID-H. As shown in Fig. 2, the ASTRID-H module now supports both expendable and reusable configurations through four core routines – Expendable/Reusable Vertical Launcher (ER-

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VT), Expendable/Reusable Horizontal Take-Off (ER-HT), Re-entry Vehicle (REV), and Human Landing System (HLS) – augmented by two supplementary landing routines for Vertical Landing (VL) and Horizontal Landing (HL).

1. Take-Off and Landing Strategies: Module Definition

	ASTRID-H					
	Configuration (T/O)			Landing		Case Study
Categories	Winged	Vertical Launcher	Lifting Body	HL	VL	
Micro Launcher		1		N/A	N/A	ML
Medium Launcher		1		N/A	N/A	MED L
Heavy Launcher		1		N/A	N/A	HEA L
Reusable Launch Vehicle 1st stage		1			4	RLV1 VTVL
		1		5		RLV1 VTHL
	2				4	RLV1 HTVL
	2			5		RLV1 HTHL
Expendable Vehicle 1st stage		1		N/A	N/A	EXP1 VT
	2			N/A	N/A	EXP1 HT
Reusable Launch Vehicle 2nd stage	2			5		RLV2 HL
		1			4	RLV2 VL
Expendable Vehicle 2nd stage		1		N/A	N/A	EXP2
Exp. Re-entry*			3	N/A	N/A	EREV
Reusable Re-Entry Vehicle *			3	5		RREV HL
					4	REV VL
Hypersonic Vehicle	2			5		HYPER
Lunar Lander		6			6	HLS

Combining the stage from Table 1 shows that the routine methodologies (ASTRID-H, HyCost) can be combined in the same way of vehicle stages.

2. Potential Vehicle Combinations (RLV - EXP): Module Blend

		Second Stage			Combination	Name	Reference vehicle
		EXP2	RLV2 VL	RLV2 HL			
First Stage	RLV1 VTVL				RLV1 VTVL - EXP2	RLV1 VTVL	RETALT 1 [1]
					RLV1 VTVL - RLV2 VL	Fully Reusable VTVL	Starship [2]
					RLV1 VTVL - RLV2 HL	Fully Reusable	
	RLV1 VTHL				RLV1 VTHL - EXP2	RLV1 VTHL	ENTRAIN (DLR) [3]
					RLV1 VTHL - RLV2 VL	Fully Reusable	
					RLV1 VTHL - RLV2 HL		
	RLV1 HTVL				RLV1 HTVL - EXP2	RLV1 HTVL	
					RLV1 HTVL - RLV2 VL	Fully Reusable	
					RLV1 HTVL- RLV2 HL		
	RLV1 HTHL				RLV1 HTHL- EXP2	RLV1 HTHL	Sanger II (1st stage) [4]
					RLV1 HTHL - RLV2 VL	Fully Reusable	
					RLV1 HTHL - RLV2 HL	Fully Reusable HTHL	Saenger II [4]
	EXP1 VT				EXP1 VT - EXP2	MED L, HEA L	Ariane 62 - 64 [5]
					EXP1 VT - RLV2 VL	RLV2 VTVL	Starship (2nd stage) [2]
					EXP1 VT - RLV2 HL	RLV2 VTHL	
	EXP1 HT				EXP1 HT - EXP2	EXP HT	
					EXP1 HT - RLV2 VL	RLV2 HTVL	
					EXP1 HT - RLV2 HL	RLV2 HTHL	

Fig. 2: iDREAM - ASTRID-H routines modularity overview.

The landing routines compute propellant consumption and the additional equipment/mass required for controlled descent, then feed those increments back into the sizing loop. This structure lets a single vehicle study switch from expendable to reusable assumptions by toggling landing logic rather than swapping entire design flows; it also keeps hypersonic, wing-assisted take-off cases within the same ER-HT backbone. Complementing this architecture, the modularity approach was derived from a survey of target categories – RLV first/second stages (VTVL/VTHL/HTHL or VL/HL), E/REVs, hypersonic vehicles, and medium/heavy launchers – so common take-off/landing strategies and reuse features are handled by shared sub-models rather than case-specific branches.

Methodologically, ASTRID-H retains the multi-fidelity conceptual/preliminary design stack established in 1.0 and continues to exchange mission analysis data with ASTOS for closure. The same design estimation logic and mass estimation workflow used for expendable microlaunchers is now re-used for RLVs, with landing increments and recovery constraints injected through the VL/HL supplements before trajectory re-optimization. This preserves the tight ASTOS-ASTRID-H loop that proved effective for 1.0 while expanding coverage to reuse-driven constraints.

HyCost. To parallel the generalized design layer, HyCost consolidates early-phase LCC into three approaches: (i) an Expendable Launchers (EXP) flow; (ii) a Reusable Space & Point-to-Point Transportation and Re-entry (RST) flow covering reusable first/second stages, HTHL/VTHL concepts, and E/REVs; and (iii) a tailored Human Landing System (HLS) routine. The RST logic introduces refurbishment, inspection/maintenance, turnaround assumptions, and cadence effects while preserving the subsystem-granular CER philosophy adopted in 1.0 so estimates remain transparent and updateable as new commercial data emerge. All three flows ingest ASTRID-H outputs directly (masses, counts, propellants, equipment) to keep architectural sensitivities intact.

TRIS. In 2.0, TRIS operates through a single roadmapping routine applied uniformly across case studies. It keeps the five-step, systems-engineering process while incorporating the recent upgrades to time/budget estimation and to resource-constrained planning that allow realistic, non-ideal roadmaps. Technologies tied to reuse (e.g., Thermal Protection System (TPS) durability, landing systems, rapid turnaround operations) can therefore be prioritized and scheduled with budget/time constraints and demonstration-asset logic, consistently across RLVs, RREVs, and hypersonic cases.

HyDat. All modules share an upgraded HyDat-backed database accessed through the in-house Database Management Library, ensuring one-source-of-truth parameters and automatic exchange of mass, cost, and roadmap evidence across studies. The same backbone that linked ASTRID-H, HyCost, and TRIS in 1.0 now anchors reuse-specific fields (e.g., landing equipment, refurbishment tasks, inspection intervals) without fragmenting the schema, which is crucial for rapid, cross-module *"what-if"* iterations.

Validation set and current status. iDREAM 2.0 is being validated against a reference vehicle set spanning vertical and horizontal recovery launchers, a reusable re-entry capsule, and a hypersonic vehicle. These cases exercise the combined ER-VT/ER-HT/REV/HLS workflows and the VL/HL landing supplements, while the corresponding EXP/RST/HLS cost flows and the unified TRIS routine are used to verify consistent propagation of design changes into affordability and maturation plans. This staged validation is intended to demonstrate that the *"few routines, broad coverage"* strategy yields AGILE prototyping across reusable and expendable regimes.

Conclusions

This paper has presented iDREAM 2.0, an integrated methodology and toolset that brings conceptual design, early cost assessment, and technology roadmapping into a single, data-consistent environment, extending the scope of iDREAM 1.0 to reusable launch systems, reusable re-entry vehicles, and hypersonic applications. The core architectural choice – few routines, broad coverage – keeps early-phase studies agile while introducing the hooks required by reusability. Concretely, ASTRID-H now organizes sizing and mission analysis through four core routines (expendable/reusable vertical launcher, expendable/reusable horizontal take-off, re-entry vehicle, and lunar lander) complemented by two landing supplements (vertical and horizontal) that inject recovery physics and landing equipment into the loop. HyCost offers three reuse-aware flows (expendable, reusable/point-to-point/re-entry, and a tailored HLS routine) to keep subsystem sensitivities visible as assumptions evolve. TRIS operates through a single, unified methodology that prioritizes and schedules maturation activities using the same evidence base as design and cost. All modules exchange parameters through an upgraded HyDat database and the in-house management library, ensuring traceability and rapid *"what-if"* propagation across the stack.

The result is a domain-opinionated environment that maintains the speed of conceptual trades while reflecting operational realities – landing increments, refurbishment and turnaround, reuse-dependent reliability and maintenance, and cadence-sensitive economics – without multiplying bespoke tools or brittle hand-offs. Current limitations are those inherent to early-phase modeling: bounded fidelity for certain subsystems, uncertainty in commercial cost data, and the need for richer representations of refurbishment policies and inspection intervals. Near-term development will focus on uncertainty propagation across design-cost-roadmap strands, deeper reliability and maintenance modeling for reusable elements, tighter links to trajectory optimization and aero/thermal pre-design and expanded sustainability metrics. With these enhancements, iDREAM 2.0 offers a practical foundation for fast, defensible decisions across a broader class of future reusable space systems.

References

[1] J. Hugues, M. Perrotin, T. Tsiodras, Using MDE for the rapid prototyping of space critical systems. In *19th IEEE/IFIP International Symposium on Rapid System Prototyping*, 2-5 Jun 2008, Monterey, CA, US, pp. 10-16. https://doi.org/10.1109/RSP.2008.19.

[2] D. Knoll, C. Fortin, A. Golkar. Review of Concurrent Engineering Design practice in the space sector: state of the art and future perspectives. In *2018 IEEE International Systems Engineering Symposium (ISSE)*, 1-3 Oct 2018, Rome, IT, pp. 1-6. https://doi.org/10.1109/SysEng.2018.8544387.

[3] Astos Solutions GmbH. ASTOS (Analysis, Simulation and Trajectory Optimization Software for Space Applications). 2025. Available online. url: astos.de/products/astos (accessed on 6 Nov 2025).

[4] D. E. Koelle. Handbook of cost engineering for space transportation systems with TRANSCOST 8.2: statistical-analytical model for cost estimation and economical optimization of launch vehicles (Rev. 4). TRANSCOST Systems: Ottobrunn, DE. 2013.

[5] V. Vercella. Cost-effective and sustainable scenarios for future reusable space transportation and re-entry systems. PhD Thesis, Politecnico di Torino. 2023.

[6] J. R. Wertz, D. F. Everett, J. J. Puschell (Eds.). Space Mission Engineering: The New SMAD. *Space Technology Library*, Microcosm Press: Torrance, CA, US. 2018.

[7] R. Phaal, C. Farrukh, D. Probert. Fast-Start Roadmapping Workshop Approaches. In *Technology Roadmapping for Strategy and Innovation*, Springer: Berlin/Heidelberg, DE, pp. 91-106, 2013. https://doi.org/10.1007/978-3-642-33923-3_6.

[8] G. Narducci, R. Fusaro, N. Viola. Technology Roadmap Methodology and Tool Upgrades to Support Strategic Decision in Space Exploration. *Aerospace, 12(8)*: 682. 2025. https://doi.org/10.3390/aerospace12080682.

[9] N. Viola, R. Fusaro, G. Narducci, G. Governale, J. Rimani, D. Ferretto, S. A. Chiusano, A. Fiori, O. Cohen, E.-M. Dupuy. iDREAM: a multi-disciplinary methodology and integrated toolset for flight vehicle engineering. In *73rd International Astronautical Congress (IAC)*, 18-22 Sep 2022, Paris, FR.

[10] Rocket Lab. ELECTRON. 2025. Available online. url: rocketlabcorp.com/launch/electron/ (accessed on 7 Nov 2025).