PROPULSION SYSTEM

Designing electric motors within the propulsion system of an eVTOL aircraft:

Labor:	$150,000	
Electrical engineers	$100,000	80$/hour
Mechanical engineers	$50,000	80$/hour
Analysis & Simulation	$200,000	
- Electromagnetic simulation software licenses & compute time		
- Thermal analysis		
- Structural finite element analysis		
- Performance mapping simulations		
Prototyping & Testing	$300,000	
- Motor controller systems		
- Test bench build		
- Instrumentation equipment		
- High voltage power supplies		
- Prototype motor fabrication		
- safety testing		
Materials:	$50,000	
- Windings		
- Magnets		
- Laminations		
- Insulations		
- Shafts/rotors		
- Controllers		
Facilities Overhead:	$100,000	
- Design office allocate costs		
- Workshop space charges		
Total Cost	$800,000	

The design of the battery system within the propulsion architecture for an eVTOL aircraft:

Engineering Labor	**$350,000**	
Electrical Engineers	$250,000	80$/hour
Mechanical Engineers	$100,000	80$/hour
Testing & Prototypes	**$600,000**	
Test bench materials and build		
Prototype cell fabrication runs		
Charge/discharge cycling testing		
Destructive test equipment		
Safety monitoring systems		
Modeling & Performance Simulation	**$200,000**	
- Electrochemical modeling software		
- Thermal simulation tools		
- Battery management system modeling		
- Lifetime prediction analytics		
Materials & Components	**$100,000**	
- Electrodes		

- Electrolytes
- Separators
- Packaging
- Battery Management Systems

Facilities Overhead Costs	**$150,000**	
- Allocate share of lab space costs		
- Equipment maintenance		
Total Cost	**$1,400,000**	

Designing the power distribution system within the propulsion architecture of an eVTOL aircraft:

Engineering Labor	**$200,000**	
Electrical engineers	$100,000	80$/hour
Systems Engineers	$100,000	100$/hour
Components & Testing:	**$350,000**	
- Wiring harnesses		
- Connectors, circuit breakers		
- Test equipment		
- Simulation models		
- Prototype boards		
Certification & Compliance	**$150,000**	
- Regulatory consulting		
- Standards compliance analysis		
- Safety audits		
Simulation Tools	**$100,000**	
- Network modeling software		
- Load flow analytics		
- Thermal modeling		
Facilities Overhead	**$50,000**	
- Allocated costs of lab space		
Total Cost	**$850,000**	

The cost of integrating the electric motors, batteries, and power distribution system into the broader pr

Here is a breakdown of the major integration cost components:

Systems Engineering: $500,000		100$/hour
- Architecting interfaces between components		
- Supporting overall propulsion system modeling		
- Managing system level requirements		
Hardware Integration	**$400,000**	
- Design and fabrication of mounting racks, enclosures		
- Wiring harnesses, piping, ducting		
- Machining and assembly setup		
Testing & Validation	**$400,000**	
- Integrated propulsion test cell/rig design		
- Instrumentation and monitoring systems		
- Safety systems for high voltage testing		
Software Integration	**$300,000**	
- Battery management system		
- Motor control integration		
- Dashboard and controls interfaces		

Facilities/Tooling Overhead	**$150,000**	
- Assembly jigs, lifting gear		
- Allocated hangar integration space costs		
Contingencies	**$250,000**	
- Covers unforeseen integration issues		
TOTAL	**$2,000,000**	

AERODYNAMICS

Designing advanced rotors for eVTOL aircraft from an aerodynamics perspective:

Wind Tunnel Testing	**$500,000**	
- Scale model fabrication		
- Wind tunnel rental		
- Instrumentation and data acquisition		
CFD Analysis:	**$400,000**	
- High performance computing cluster access charges		
- CFD software licenses		
- Modeling engineers		
Materials & Prototyping:	**$350,000**	
- Tooling for blade molds		
- Specialized lightweight composites		
- 3D printing design iterations		
Engineering Labor:	**$300,000**	
- Aerodynamics engineers		80$/hour
- Stress analysis engineers		60$/hour
- Wind tunnel test engineers		60$/hour
Facilities Overhead:	**$100,000**	
- Wind tunnel maintenance		
- Workshop space allocation		
Travel & Transport:	**$50,000**	
- Shipping scale models		
- Engineer travel		
Total Cost	**$1.7 million**	

Designing the flight control surfaces from an aerodynamics perspective for an eVTOL aircraft:

Wind Tunnel Testing:	**$400,000**
- Scaled model fabrication	
- Installation and instrumentation	
- Tunnel rental for testing	
Computational Fluid Dynamics:	**$300,000**
- High fidelity CFD software licenses	
- Cloud compute cluster charges	
- Engineers/analysts	
Prototyping & Materials:	**$200,000**
- Rapid prototyping design iterations	
- Carbon fiber and other composites	
- 3D printed scale models	
Engineering Labor:	**$250,000**

- Aerodynamics engineers		80$/hour
- Design engineers		60$/hour
- Tunnel test engineers		60$/hour
Overhead Costs:	**$100,000**	
- Wind tunnel maintenance		
- Workshop space allocation		
Travel & Logistics:	**$50,000**	
- Shipping physical models		
- Engineer travel		
Total Cost	**$1.3 million**	

The estimated cost for integrating advanced rotors and flight control surfaces from an aerodynamics per

Systems Analysis:	**$300,000**	
- Cross-functional performance tradeoffs evaluation		
- Integrated computational fluid dynamics analysis		
- Handling quality studies		
Simulation Upgrades:	**$250,000**	
- Enhanced modeling of component interactions		
- Higher fidelity aerodynamic modeling integration		
- Expanded modeling functionality		
Wind Tunnel Testing:	**$400,000**	
- Integrated scaled model fabrication		
- Additional test instrumentation		
- Extended wind tunnel testing		
Engineering Labor:	**$200,000**	
- Aerodynamics lead engineers		80$/hour
- Specialists for rotor-surface interactions		60$/hour
Prototype Iterations:	**$150,000**	
- Refining integrated designs		
- Additional test articles		
Travel & Logistics:	**$50,000**	
- Managing external test facilities		
Contingencies:	**$150,000**	
- Reserves for unanticipated issues		
Total:	**$1.5 million**	

LANDING GEAR

Designing a landing gear system for an eVTOL aircraft:

Engineering Labor:	**$200,000**	
- Mechanical design engineers		80$/hour
- Loads & dynamics analysis		80$/hour
Prototyping & Testing:	**$400,000**	
- Landing gear structural prototypes		
- Drop test rigs & instrumentation		
- Workshops and tooling		
Materials &Processes:	**$100,000**	
- Aluminum/titanium alloys		

- Composite materials
- Fabrication process R&D

Modeling & Simulation:	**$150,000**	
- FEA structural modeling software		
- Kinematic and fatigue analysis		
- Failure mode analysis		
Certification Support:	**$100,000**	
- Regulatory compliance analysis		
- Safety standards consultation		
Sourcing & Quality:	**$50,000**	
- Supplier surveys and audits		
- Defining QA standards		
Total Cost =	**$1 million**	

Designing the chassis of an eVTOL aircraft:

Engineering Labor:	**$250,000**	
- Mechanical design engineers		80$/hour
- Structural analysis engineers		60$/hour
- Weight optimization engineers		60$/hour
Materials & Processes:	**$150,000**	
- Aluminum, titanium, composites		
- Additive manufacturing		
- Finishing processes		
Modeling & Simulation:	**$200,000**	
- FEA structural modeling software		
- Topology optimization tools		
- Crashworthiness analysis		
Prototype Production:	**$300,000**	
- CNC machined test articles		
- Tooling for composite materials		
- Assembly jigs & fixtures		
Testing & Validation:	**$250,000**	
- Static, fatigue, burst testing		
- Instrumentation and data acquisition		
Facilities Overhead:	**$100,000**	
- Workshop and lab space		
- Equipment maintenance		
Total Cost =	**$1.25 million**	

EXTERNAL FUESLAGE

<u>Designing the external lighting system on an eVTOL aircraft fuselage:</u>

Engineering Labor:	**$100,000**	
- Electrical engineers		80$/hour
- Mechanical engineers		80$/hour
- Technicians		60$/hour
Components:	**$150,000**	
- LEDs, bezels, optics, heat sinks		

- Connectors, wiring
- Light controllers

Modeling & Analysis: **$50,000**
- Thermal modeling
- Illumination field modeling
- Structural finite element analysis

Testing & Certification: **$100,000**
- Light output characterization
- Vibration, temperature testing
- EMI/EMC certification tests

Prototyping: **$75,000**
- PCB subsystem builds
- Bezel tooling and parts
- Assembly jigs & fixtures

Facilities Allocation: **$25,000**
- Lab equipment and space

Total: **$500,000**

Designing and integrating external sensors on an eVTOL aircraft fuselage:

Sensor Hardware: **$200,000**
- Cameras, LiDARs, radars, ultrasonics
- Sensor processing units
- Lens, bezels, mounting hardware

Integration Labor: **$300,000**
- Mechanical engineers
- Electrical engineers
- Technicians

Testing & Certification: **$150,000**
- Sensor characterization
- Environmental testing
- Safety certifications

Modeling & Simulations: **$100,000**
- Sensor placement optimizations
- Structural, thermal, aerodynamic analysis

Prototyping: **$100,000**
- Sensor test rig builds
- Rapid prototyped mounts
- Custom cabling builds

Facilities Overhead: **$50,000**
- Lab equipment and workspace

Total Cost = **$900,000**

INTERNAL FUSELAGE

Designing and integrating passenger seating inside an eVTOL aircraft fuselage:

Seat Design: **$200,000**

- Ergonomic design studies		
- Structural analysis		
- Custom cushioning		
Integration Engineering:	**$250,000**	
- Electrical engineers		80$/hour
- Mechanical engineers		80$/hour
- Technicians		60$/hour
Prototyping & Testing:	**$300,000**	
- Prototype seat builds		
- Occupant testing and evaluation		
- Crash/impact testing		
Modeling and Simulation:	**$150,000**	
- Occupant space modeling		
- Structural simulations		
- Emergence egress analysis		
Certification & Compliance:	**$100,000**	
- Regulatory consulting		
- Flammability testing		
Interior Modifications:	**$50,000**	
- Mounts, flooring, fittings		
Total Cost =	**$1,050,000**	

Designing and integrating the cabin interior within an eVTOL aircraft fuselage:

Industrial Design:	**$200,000**	
- Cabin architecture concepts		
- 3D interior modeling		
- User experience design		
Engineering:	**$300,000**	
- Mechanical engineers		80$/hour
- Electrical engineers		80$/hour
- Technicians for integration		60$/hour
Prototyping and Fabrication:	**$250,000**	
- Cabin mockups		
- Custom interior parts		
- Support tooling and jigs		
Testing and Evaluation:	**$150,000**	
- Human factors evaluations		
- Structural assessments		
- Safety audits		
Certification Compliance:	**$100,000**	
- Regulatory consulting		
- Flammability testing		
- Toxicity analysis		
Program Management:	**$50,000**	
- Design partners coordination		
Total Cost =	**$1,050,000**	

Designing and integrating an environmental control system (ECS) inside the fuselage of an eVTOL aircraf

HVAC System Design:	**$250,000**	
- Thermal load analysis		
- Heat exchanger sizing		
- Airflow dynamic modeling		
Integration Engineering:	**$200,000**	
- Mechanical engineers		80$/hour
- Electrical engineers		80$/hour
- Avionics technicians		60$/hour
Prototypes & Testing:	**$300,000**	
- Environmental chamber rentals		
- Cooling/heating test rig builds		
- Thermal sensor instrumentation		
Ventilation Architecture:	**$150,000**	
- Cabin airflow CFD analysis		
- Ducting optimization		
Certification Support:	**$100,000**	
- Cabin environment standards		
- Toxic gas containment		
Program Management:	**$50,000**	
- Multi-vendor coordination		
Total Cost =	**$1,050,000**	

AVIONICS

<u>Designing and integrating fuel cell (FC) systems for avionics in electric vertical takeoff and landing (eVTO</u>

Research & Development	
Fuel cell system conceptual design	$150,000
Prototyping and bench testing	$350,000
Integrated system simulations and modeling -	$200,000
Safety analyses and compliance planning -	$100,000
Integration & Testing	
Avionics integration and interfaces	$250,000
Environmental testing (thermal, vibration, etc.	$300,000
Flight testing and certification -	$500,000
Recurring Production Costs	
Fuel cell stacks/modules -	$20,000 each
Balance of plant components -	$15,000 per system
Avionics interfaces and wiring -	$10,000 per aircraft
Assembly and integration labor -	$5,000 per aircraft

Non-Recurring Production Costs

- Production facility/tools - $1M
- Production planning, training - $250,000

Total NRE (non-recurring engineering) - $1.6M

Total per aircraft cost - $50,000

(For estimated production volume of 100 aircraft)

Designing and integrating navigation systems for avionics on electric vertical takeoff and landing (eVTOL
Research & Development
- Requirements definition - $100,000
- Sensor selection & integration plans - $250,000
- Navigation algorithm development - $350,000
- Avionics simulation testing - $150,000
- Lab prototype development - $400,000

Integration & Testing
- Sensor integration with avionics - $300,000
- Navigation software integration - $250,000
- Hardware-in-the-loop testing - $200,000
- Flight testing and certification - $500,000

Recurring Production Costs
- Sensors (GPS, inertial, etc.) - $15,000 per aircraft
- Navigation computers - $5,000 per aircraft
- Integration and wiring - $1,500 per aircraft

Non-Recurring Production Costs
- Production facility/tools - $500,000
- Production planning, training - $150,000

Total NRE - $2M
Total per aircraft cost - $21,500
(Estimated production volume of 100 aircraft)

Designing and integrating communication systems for avionics on electric vertical takeoff and landing (e
Research & Development
- Requirements definition - $150,000
- Systems architecture design - $200,000
- Radio and antenna selection & integration - $300,000
- Communication protocol development - $250,000
- Avionics interface and simulations - $200,000
- Lab prototype testing - $350,000

Integration & Testing
- Communication system integration - $250,000
- Radio/antenna installation - $150,000
- Ground station integration - $100,000
- Flight testing and certification - $400,000

Recurring Production Costs
- Radios and antennas - $10,000 per aircraft
- Cabling and interfaces - $1,500 per aircraft

Non-Recurring Production Costs
- Production facility/tools - $500,000
- Production planning, training - $100,000

Total NRE - $2.3M
Total per aircraft cost - $11,500
(Estimated production volume of 100 aircraft)

Estimated labor costs for integrating navigation, fuel cell (FC), and communications systems into the avi

Navigation Systems

- Integration Engineering - $80,000
- Software Development - $60,000
- Hardware Design/Integration - $50,000
- Testing & Evaluation - $40,000

Total: $230,000

Fuel Cell Systems

- Integration Engineering - $100,000
- Fuel Cell Tech Design - $60,000
- Avionics Interfaces - $45,000
- Testing & Certification - $60,000

Total: $265,000

Communications Systems

- Systems Engineering - $55,000
- Software Development - $65,000
- Hardware/Antenna Integration - $40,000
- Testing & Evaluation - $35,000

Total: $195,000

Program Management - $150,000

Total Labor Costs:

Navigation Systems: $230,000
Fuel Cell Systems: $265,000
Communications Systems: $195,000
Program Management: $150,000
Grand Total: $840,000

Assumptions:

- Labor rates around $80-$100/hr
- 500-800 labor hours per system
- Built into 10 prototype aircraft
- Includes management labor

SAFETY

Designing and integrating emergency landing systems for electric vertical takeoff and landing (eVTOL) ai

Research & Development

- Requirements definition - $100,000
- Concept trade studies - $150,000
- Software simulations and modeling - $250,000
- Prototype hardware development - $300,000
- Test facility/equipment - $400,000
- Landing tests (water, ground) - $600,000

Integration & Testing

- Airframe structure integration - $200,000
- Avionics interfacing - $150,000
- Flotation systems - $100,000
- Parachute systems - $250,000

- Landing gear modifications - $200,000
- Flight test (with crew) - $800,000

Recurring Production Costs

- Parachutes - $15,000 per aircraft
- Flotation bags/mods - $10,000 per aircraft
- Landing gear mods - $5,000 per aircraft

Non Recurring Production Costs

- Production design/setup - $500,000
- Training and documentation - $100,000

Total NRE - $3.85 million
Total per Aircraft Cost - $30,000

Cost breakdown for redundancy mechanisms into an electric vertical takeoff and landing (eVTOL) aircraf

Research & Development

- Requirements gathering - $50,000
- Architecture trade studies - $150,000
- Reliability modeling and analysis - $200,000
- Controls/software development - $300,000
- Prototype hardware - $400,000
- Integrated testing - $500,000

Integration & Testing

- Avionics interfaces - $150,000
- Hardware integration - $250,000
- Electrical redundancy - $100,000
- Mechanical linkage backups - $200,000
- Fault injection testing - $300,000
- Certification planning - $100,000

Recurring Production Costs

- Redundant avionics - $15,000 per aircraft
- Mechanical components - $5,000 per aircraft

Non Recurring Production Costs

- Production setup/tooling - $800,000
- Process documentation - $100,000

Total NRE - $2.6 million
Total Per Aircraft - $20,000

(Estimated production volume of 100 aircraft)

Designing and integrating a collision avoidance system for an electric vertical takeoff and landing (eVTO

Research & Development

- Requirements definition - $100,000
- Sensor trade studies - $150,000
- Alerting/display interfaces - $200,000
- Detection algorithms - $300,000
- Simulation and modeling - $250,000
- Prototype testing - $400,000

Integration & Testing

- Sensor installation - $300,000
- Avionics integration - $250,000
- Software implementation - $200,000
- Flight testing - $600,000
- Certification planning - $100,000

Recurring Production Costs

- Sensors (cameras, radar) - $15,000 per aircraft
- Computing hardware - $5,000 per aircraft
- Software licenses - $5,000 per aircraft

Non-Recurring Production Costs

- Production setup/tooling - $500,000
- Training and documentation - $100,000

Total NRE - $2.45 million
Total Per Aircraft - $25,000
(Estimated production volume 100 aircraft)

labor costs for integrating redundancy mechanisms, collision avoidance, and emergency landing systems

Redundancy Mechanisms

- Systems Architecture: $100,000
- Controls Integration: $150,000
- Avionics Interfaces: $80,000
- Software: $120,000
- Testing: $100,000

Total: $550,000

Collision Avoidance

- Sensor Integration: $90,000
- Alerting Interfaces: $60,000
- Detection Algorithms: $140,000
- Simulation & Modeling: $100,000
- Flight Testing: $60,000

Total: $450,000

Emergency Landing

- Requirements & Concept Study: $80,000
- Avionics Integration: $100,000
- Parachutes/Flotation Design: $120,000
- Landing Gear Mods: $90,000
- Flight Testing: $100,000

Total: $490,000

Program Management: $200,000
Total Labor:
Redundancy: $550,000
Collision Avoidance: $450,000
Emergency Landing: $490,000
Management: $200,000
Grand Total: $1.69 million

Assumptions:
- 500-1000 engineering hours per system

- Average labor rate of $100/hr
- Built into 10 prototype aircraft

SOFTWARE

Designing and developing flight control software for an electric vertical takeoff and landing (eVTOL) aircraf
Research & Development
- Requirements definition - $150,000
- Architecture trade studies - $200,000
- Control laws development - $350,000
- Simulation and modeling - $300,000
- Algorithm verification - $250,000
- Prototype testing - $400,000

Integration & Testing
- Avionics interfacing - $200,000
- Software implementation - $350,000
- Hardware-in-the-loop testbed - $500,000
- Flight control testing - $600,000
- Certification planning - $150,000

Recurring Costs
- Flight computers - $15,000 per aircraft
- Software licenses - $5,000 per aircraft

Non-Recurring Production Costs
- Software tools customization - $250,000
- Developer training - $100,000

Total NRE: $3.15 million
Total Per Aircraft: $20,000
(Estimated production volume 100 aircraft)

Labor costs:
Research & Development
- Requirements & Architecture - $300,000
  - Systems Engineers: $150,000
  - Software Architects: $100,000
  - Project Management: $50,000
- Control Laws
  - Controls Engineers: $400,000
  - Software: $200,000
  - Simulation: $100,000
- Verification & Validation
  - Test Engineers: $350,000
  - Platforms & Tools: $200,000

Integration & Testing
- Avionics Interfaces
  - Systems: $250,000
  - Software: $200,000
- Flight Testing

  - Engineers: $400,000
  - Flight Test Support: $300,000
- Certification Management
  - Planning Team: $250,000
Total Labor: $2.55 million
Total Non-Labor Costs: $1 million
Total NRE: $3.55 million
Per Aircraft Costs:
  - Recurring Software Licenses: $5,000
  - Flight Computers: $15,000
Assumptions:
- Engineering time 100k-150k per engineer
- 50-150 engineers based on system
- Flight test with 5 prototype aircraft

Designing and integrating a flight data transmission system for an electric vertical takeoff and landing (eVT
Research & Development
- Requirements definition - $100,000
- System architecture design - $150,000
- Radio and antenna selection - $200,000
- Communication protocol dev - $250,000
- Encryption and cybersecurity - $300,000
- Prototype testing - $350,000
Integration & Testing
- Avionics interfaces - $200,000
- Radio/antenna installation - $150,000
- Ground station integration - $100,000
- Cloud data infrastructure - $250,000
- Flight testing - $300,000
- Certification planning - $50,000
Recurring Production Costs
- Airborne radios - $3,000 per aircraft
- Data servers/software - $2,000 per aircraft
Non-Recurring Costs
- Production facility/tools - $500,000
- Setup and training - $100,000
Total NRE - $2.9 million
Total Per Aircraft - $5,000
(Estimated production volume of 100 aircraft)

Labor costs:
Research & Development
- Systems Architecture
  - Systems Engineers: $200,000
  - Software Architects: $150,000
- Communication Protocols
  - Software Dev: $350,000

  - Testing: $150,000
- Encryption & Cybersecurity
  - Software: $250,000
  - Testing & Compliance: $200,000
- Prototype Testing
  - Engineers: $300,000
  - Equipment: $200,000

Integration & Testing

- Avionics Integration
  - Engineering: $150,000
  - Tech Writers: $50,000
- Ground Systems
  - Networks/Cloud: $350,000
  - Software: $150,000
- Flight Testing
  - Engineers: $250,000
  - Flight Test Equipment: $200,000

Total Labor: $2.6 million

Total Non-labor: $1.5 million

Total NRE: $4.1 million

Recurring Per Aircraft:

  - Transceivers: $3,000
  - Data Servers: $2,000

Assumptions:

- 100-150k per systems/software engineer
- Compliance team for security
- 5 aircraft for flight testing

opulsion system architecture of an eVTOL aircraft can be estimated in the range of $2 million.