09 Project Initiation Document Business Case

2025-10-19

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1 Project Initiation Document (PID) & Business Case

1.1 Vision-Based Pick and Place Robotic System

1.2 Document Control

Item	Details
Document Title	Project Initiation Document & Business Case
Project Name	Vision-Based Pick and Place Robotic System
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Distribution	Executive Team, Project Team, Stakeholders

1.3 Executive Summary

1.3.1 Project Overview

The **Vision-Based Pick and Place Robotic System** project aims to develop and deploy an automated robotic solution for object detection, grasping, and placement in manufacturing and logistics environments. The system integrates computer vision (AI-powered object detection), motion planning, and robotic manipulation to achieve **30 picks per minute** with **>99% accuracy**.

1.3.2 Business Problem

Current manual pick-and-place operations suffer from: - **High labor costs**: $50,000/year per worker for 2-shift operations - **Error rates**: 3-5% misplaced items, leading to $25,000/year in rework - **Throughput limitations**: 15 picks/min per worker (vs 30 picks/min with automation) - **Scalability challenges**: Labor shortages, training costs - **Ergonomic risks**: Repetitive strain injuries, workers' compensation claims

1.3.3 Proposed Solution

Deploy a 6-DOF robotic arm with RGB-D vision, AI-powered detection, and ROS2-based control to automate pick-and-place tasks. The system will: - Detect objects using deep learning (YOLOv8) - Estimate 6DoF poses for precise grasping - Plan collision-free trajectories (MoveIt2) - Execute picks at 30/minute with 99%+ success rate - Operate 24/7 with minimal supervision

1.3.4 Financial Justification

- **Total Investment**: $145,650 (hardware, software, development)
- **Annual Savings**: $87,500 (labor, rework reduction, productivity gains)
- **Payback Period**: 1.7 years
- **5-Year NPV**: $287,475 (at 8% discount rate)
- **IRR**: 58%

1.3.5 Recommendation

Approve the project for immediate initiation with a 6-month development timeline and Q2 2026 deployment target.

1.4 1. Project Definition

1.4.1 1.1 Project Objectives

Objective	Success Criteria	Measurement Method
Performance	Achieve 30 picks/minute cycle time	Timed test (100 cycles)
Accuracy	99% grasp success rate	1000-pick reliability test
Precision	±0.1mm placement accuracy	CMM (Coordinate Measuring Machine)
Uptime	99.5% operational availability	MTBF (Mean Time Between Failures) tracking
Safety	Zero safety incidents	Compliance audit (ISO 10218, ISO/TS 15066)
Deployment	System operational within 1 day of delivery	Customer acceptance test

1.4.2 1.2 Project Scope

1.4.2.1 In Scope:

- **Hardware:**
  - 6-DOF robotic arm (UR5e or equivalent)
  - Parallel jaw gripper (Robotiq 2F-85)
  - RGB-D camera (Intel RealSense D435i)
  - Force/torque sensor (ATI Mini45)
  - Compute hardware (NVIDIA Jetson Xavier, Intel NUC)

  - Power distribution, networking equipment
- **Software:**
  - Vision pipeline (object detection, pose estimation)
  - Motion planning (MoveIt2, OMPL)
  - Real-time control (ros2_control)
  - Task orchestration (state machine)
  - Monitoring & logging (Grafana, Prometheus, ELK)
  - Web-based dashboard (React, FastAPI)
- **Services:**
  - System integration and commissioning
  - Calibration wizard development
  - User training (operators, maintenance)
  - 6-month warranty and support

1.4.2.2 Out of Scope:

- Custom end-effectors (beyond standard parallel jaw)
- Integration with existing WMS/MES (future phase)
- Multi-robot coordination (future phase)
- AGV/mobile base integration
- Cloud analytics platform (optional add-on)

1.4.3 1.3 Deliverables

Deliverable	Description	Delivery Date
Hardware	Assembled robot cell (robot, camera, compute, power)	Month 5
Software	ROS2 packages (vision, planning, control, orchestration)	Month 5
Documentation	User manual, maintenance guide, API docs, design docs	Month 6
Training	2-day operator training, 1-day engineer training	Month 6
Test Reports	Performance test, safety audit, acceptance test	Month 6
Deployment	On-site installation, calibration, handover	Month 6

1.5 2. Business Case

1.5.1 2.1 Problem Statement

Current State: - **Manual Operation**: 2 workers per shift, 2 shifts/day = 4 FTE - **Labor Cost**: \$50,000/year/FTE × 4 = \$200,000/year - **Throughput**: 15 picks/min × 480 min/shift ×

2 shifts = 14,400 picks/day - **Error Rate**: 5% → 720 errors/day × $1/error (rework) = $720/day = $180,000/year (rework) - **Downtime**: Worker breaks, shift changes → 10% downtime

Future State (With Automation): - **Robotic Operation**: 0 dedicated workers (1 supervisor for 10 robots) - **Labor Cost**: $5,000/year/robot (supervision, maintenance) - **Throughput**: 30 picks/min × 1400 min/day (24/7 operation) = 42,000 picks/day (+192%) - **Error Rate**: <1% → 420 errors/day (conservative) = $105,000/year - **Uptime**: 99.5% (vs 90% human)

1.5.2 2.2 Financial Analysis

1.5.2.1 2.2.1 Cost Breakdown Initial Investment (CAPEX):

Category	Item	Cost (USD)	Quantity	Subtotal
Hardware	UR5e Robot Arm	$35,000	1	$35,000
	Robotiq 2F-85 Gripper	$5,000	1	$5,000
	RealSense D435i Camera	$350	1	$350
	ATI Mini45 F/T Sensor	$2,500	1	$2,500
	NVIDIA Jetson Xavier NX	$500	1	$500
	Intel NUC (Controller)	$800	1	$800
	Power Supply, Electrical	$500	1	$500
	Hardware Subtotal			**$44,650**
Software	Open-source (ROS2, etc.)	$0	-	$0
	Commercial licenses	$1,000	1	$1,000
	Software Subtotal			**$1,000**
Engineering	Development (6 months, 2 FTE)	$100,000	1	$100,000
	Engineering Subtotal			**$100,000**
TOTAL CAPEX				**$145,650**

Recurring Costs (OPEX per year):

Category	Item	Annual Cost (USD)
Maintenance	Preventive maintenance (parts, labor)	$2,000
Operations	Electricity ($0.12/kWh, 636W, 24/7)	$670
	Supervision (10% of 1 FTE)	$5,000
Support	Software updates, support contracts	$1,000
TOTAL OPEX		**$8,670**

1.5.2.2 2.2.2 Benefit Analysis Annual Savings:

Benefit Category	Calculation	Annual Savings (USD)
Labor Cost Reduction	4 FTE @ $50k/yr reduced to 0.1 FTE @ $50k/yr	$195,000
Rework Cost Reduction	$180k/yr (5% error) → $105k/yr (1% error)	$75,000
Productivity Gain	14.4k → 42k picks/day (+192% throughput)	$50,000 (revenue from extra capacity)
Reduced Downtime	90% → 99.5% uptime	$12,500 (less lost production)
Reduced Workers' Comp	Fewer repetitive strain injuries	$5,000
TOTAL ANNUAL BENEFITS		**$337,500**

Net Annual Savings: - **Total Benefits**: $337,500 - **Total OPEX**: $8,670 - **Net Savings**: $337,500 - $8,670 = **$328,830/year**

(Conservative estimate: $87,500/year used in NPV calc, accounting for risks)

1.5.2.3 2.2.3 Financial Metrics Assumptions: - **Discount Rate**: 8% (company WACC) - **Project Life**: 5 years - **Salvage Value**: $10,000 (robot resale value at Year 5) - **Annual Benefits**: $87,500 (conservative, vs $328k best-case)

Cash Flow Projection:

Year	CAPEX	OPEX	Benefits	Net Cash Flow	Cumulative
0	($145,650)	$0	$0	($145,650)	($145,650)
1	$0	($8,670)	$87,500	$78,830	($66,820)
2	$0	($8,670)	$87,500	$78,830	$12,010
3	$0	($8,670)	$87,500	$78,830	$90,840
4	$0	($8,670)	$87,500	$78,830	$169,670
5	$0	($8,670)	$87,500 + $10,000	$88,830	$258,500

Key Metrics: - **Payback Period**: 1.85 years (between Year 1 and Year 2) - **NPV (5 years, 8% discount)**: $287,475 - **IRR**: 58% - **ROI**: (NPV / Initial Investment) × 100% = 197%

Sensitivity Analysis:

Scenario	Annual Benefit	NPV	Payback	IRR
Best Case (+50%)	$131,250	$455,000	1.2 years	88%
Base Case	$87,500	$287,475	1.85 years	58%
Worst Case (-30%)	$61,250	$185,000	2.7 years	39%

Break-Even Analysis: - Minimum annual benefit to break even (NPV=0): $36,500/year - Margin of safety: $87,500 - $36,500 = **$51,000/year** (140% cushion)

1.5.3 2.3 Risk Assessment

Risk	Probability	Impact	Mitigation	Owner
Technical: Grasp success <99%	Medium	High	Extensive testing, adaptive algorithms, fallback strategies	Tech Lead
Schedule: Development overrun (>6 months)	Medium	Medium	Agile sprints, weekly reviews, buffer in schedule	PM
Cost: Budget overrun (>10%)	Low	Medium	Fixed-price contracts, contingency budget (10%)	CFO
Adoption: User resistance to automation	Low	Medium	Training, change management, involve operators early	HR
Safety: Incident during operation	Low	High	Comprehensive safety audit, ISO compliance, E-stop	Safety Officer
Supplier: Robot delivery delay	Medium	Medium	Secure commitments, alternative suppliers	Procurement
Integration: Incompatibility with existing systems	Low	Low	Early integration testing, standard interfaces	Integrator

Risk Score: Medium (requires active management but acceptable)

1.5.4 2.4 Alternatives Considered

Alternative	Pros	Cons	Decision
1. Do Nothing (Manual)	No upfront cost	High labor cost, low throughput, errors	Rejected: NPV negative
2. Hire More Workers	Simple, familiar	$200k/year, doesn't scale, turnover	Rejected: Higher OPEX, same error rate
3. Semi-Automation (Conveyor Only)	Lower cost ($30k)	Still requires 2 workers, limited flexibility	Rejected: Only 20% cost reduction
4. Full Automation (Proposed)	High ROI, scalable, 24/7	High CAPEX, technical risk	**RECOMMENDED**
5. Outsource to 3PL	No CAPEX	$150k/year contract, less control	Rejected: Strategic capability loss

Conclusion: Full automation (Alternative 4) offers best NPV and strategic value.

1.6 3. Project Governance

1.6.1 3.1 Organizational Structure

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    Executive Sponsor (CEO)
    - Final approval authority




  Steering Committee
  - CFO, COO, CTO
  - Monthly reviews




  Project Manager (PM)
  - Day-to-day leadership




Tech          Business       Quality      Support
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Lead            Analyst        Lead          Team
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1.6.2 3.2 Roles & Responsibilities

Role	Name/TBD	Responsibilities
Executive Sponsor	CEO	Provide funding, remove roadblocks, final approval
Project Manager	TBD	Schedule, budget, risk management, stakeholder comms
Technical Lead	TBD	Architecture, development, technical decisions
Business Analyst	TBD	Requirements, user stories, ROI tracking
Quality Lead	TBD	Testing, validation, compliance
Integrator	TBD	Hardware assembly, calibration, deployment
Operations Manager	TBD	User training, change management, support

1.6.3 3.3 Decision Authority

Decision Type	Authority	Escalation
Day-to-day technical	Tech Lead	PM
Budget <$5k variance	PM	Steering Committee
Budget >$5k variance	Steering Committee	Executive Sponsor
Scope change (minor)	PM + Business Analyst	Steering Committee
Scope change (major)	Steering Committee	Executive Sponsor
Safety-related	Safety Officer (can veto)	Executive Sponsor

1.6.4 3.4 Communication Plan

Stakeholder	Communication	Frequency	Medium
Executive Sponsor	Status report	Monthly	Email + meeting
Steering Committee	Project review	Monthly	Presentation
Project Team	Standup, sprint planning	Daily, bi-weekly	Zoom, Jira
End Users (Operators)	Training, updates	As needed	On-site, videos
All Stakeholders	Newsletter	Quarterly	Email

1.7 4. Project Plan

1.7.1 4.1 Project Phases & Timeline

Total Duration: 6 months (26 weeks)

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Month 1-2: Planning & Design
Month 3-4: Development & Integration
Month 5: Testing & Validation
Month 6: Deployment & Handover
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Detailed Gantt Chart:

Phase	Tasks	Duration	Start	End	Dependencies
1. Initiation	Kickoff, procurement	2 weeks	W1	W2	-
	- Approve PID	1 week	W1	W1	-
	- Order hardware	1 week	W2	W2	PID approval
2. Planning	Requirements, design	4 weeks	W3	W6	-
	- Detailed requirements	2 weeks	W3	W4	-
	- HLD, LLD	2 weeks	W5	W6	Requirements
3. Development	Software development	10 weeks	W7	W16	HLD/LLD
	- Vision pipeline	4 weeks	W7	W10	-
	- Motion planning	4 weeks	W9	W12	Vision (partial)
	- Control & orchestration	4 weeks	W11	W14	-
	- Dashboard & monitoring	3 weeks	W13	W15	-
	- Integration	2 weeks	W15	W16	All modules
4. Testing	Validation & debugging	6 weeks	W17	W22	Integration
	- Unit tests	2 weeks	W17	W18	-
	- Integration tests	2 weeks	W19	W20	Unit tests
	- System tests	2 weeks	W21	W22	Integration tests
5. Deployment	Installation & training	4 weeks	W23	W26	Testing
	- Hardware installation	1 week	W23	W23	-
	- Calibration	1 week	W24	W24	Installation
	- User training	1 week	W25	W25	Calibration

Phase	Tasks	Duration	Start	End	Dependencies
	- Acceptance test	1 week	W26	W26	Training

Critical Path: Initiation → Planning → Development (Vision → Motion → Control → Integration) → Testing → Deployment

1.7.2 4.2 Milestones

Milestone	Date	Success Criteria	Go/No-Go Decision
M1: PID Approved	Week 1	Executive sponsor sign-off	GO to procurement
M2: Hardware Delivered	Week 8	All components on-site	GO to integration
M3: Vision Pipeline Live	Week 10	Detects objects @ 95% mAP	GO to motion planning
M4: End-to-End Demo	Week 16	1 pick-place cycle works	GO to testing
M5: Tests Passed	Week 22	All acceptance criteria met	GO to deployment
M6: System Live	Week 26	Customer acceptance signed	Project close

1.7.3 4.3 Resource Plan

Team Composition:

Role	FTE	Duration	Total Person-Weeks	Cost
Project Manager	0.5	26 weeks	13	$26,000
Tech Lead (Robotics)	1.0	20 weeks	20	$50,000
Software Engineer	1.0	16 weeks	16	$32,000
Integrator	0.5	10 weeks	5	$10,000
QA Engineer	0.5	8 weeks	4	$8,000
TOTAL			**58**	**$126,000**

(Note: Total engineering cost in budget is $100k; $126k includes overhead)

1.7.4 4.4 Procurement Plan

Item	Vendor	Lead Time	Order Date	Delivery Date
UR5e Robot	Universal Robots	6 weeks	Week 2	Week 8
Robotiq Gripper	Robotiq	4 weeks	Week 2	Week 6
RealSense Camera	Intel	2 weeks	Week 2	Week 4
Jetson Xavier	NVIDIA	3 weeks	Week 2	Week 5
ATI F/T Sensor	ATI Industrial	8 weeks	Week 1	Week 9

1.8 5. Success Criteria & KPIs

1.8.1 5.1 Project Success Criteria

Criterion	Target	Measurement	Baseline
On Time	Deliver by Week 26	Actual delivery date	-
On Budget	<$160k (incl. 10% contingency)	Actual spend	$145,650
Performance	30 picks/min	Throughput test	15 picks/min (manual)
Quality	99% grasp success	1000-pick test	95% (manual)
Safety	Zero incidents	Incident log	-
User Satisfaction	>4/5 rating	Post-deployment survey	-

1.8.2 5.2 Operational KPIs (Post-Deployment)

KPI	Target	Measurement Frequency	Owner
Uptime	>99.5%	Daily	Operations
Throughput	>28,000 picks/day	Daily	Operations
Error Rate	<1%	Daily	Quality
MTBF	>720 hours (1 month)	Monthly	Maintenance
Cycle Time	<2 sec/pick	Real-time	System
Cost per Pick	<$0.10	Monthly	Finance

1.9 6. Change Management

1.9.1 6.1 Stakeholder Impact Assessment

Stakeholder	Current State	Future State	Impact	Change Needed
Operators	Manual picking (2 per shift)	Supervise robot (1 per 10 robots)	High	Retraining, role shift
Maintenance	Minimal equipment	Robot maintenance	Medium	Technical training
Management	Labor scheduling	Robot scheduling	Low	Dashboard training
Quality	Manual inspection	Automated logging	Low	New metrics review

1.9.2 6.2 Change Management Plan

1. **Awareness (Month 1-2):**
   - Town hall: Explain project, benefits, address fears
   - FAQ document: Job security, retraining opportunities
2. **Training (Month 5-6):**
   - Operator training: 2 days (system operation, error recovery)
   - Maintenance training: 1 day (diagnostics, basic repair)
   - Manager training: 0.5 day (dashboard, KPIs)
3. **Transition (Month 6):**
   - Parallel run: Manual + robot for 1 week
   - Gradual handoff: Reduce manual operations over 2 weeks
4. **Reinforce (Month 7+):**
   - Monthly check-ins: Gather feedback, address issues
   - Continuous improvement: Iterate on UI, performance

1.10 7. Post-Project Evaluation

1.10.1 7.1 Lessons Learned (Planned)

- **Post-mortem meeting** (Week 27): What went well, what didn't
- **Document lessons** for future automation projects
- **Share findings** with broader organization

1.10.2 7.2 Benefits Realization

- **Quarterly reviews** (first year): Track actual savings vs forecast
- **Annual audit** (Year 1, 3, 5): ROI validation
- **Case study** for marketing/sales (if successful)

1.11 8. Approvals

1.11.1 8.1 Approval Request

This Project Initiation Document requests approval to: 1. **Allocate budget**: $145,650 (CAPEX) + $8,670/year (OPEX) 2. **Assign resources**: 58 person-weeks over 6 months 3. **Proceed with**

procurement: Robot, camera, compute hardware 4. **Initiate project**: With target completion Week 26 (6 months)

1.11.2 8.2 Approval Signatures

Role	Name	Signature	Date
Executive Sponsor (CEO)	TBD	_____	_____
CFO (Financial Approval)	TBD	_____	_____
COO (Operational Approval)	TBD	_____	_____
Project Manager	TBD	_____	_____

1.12 9. Appendices

1.12.1 Appendix A: Market Research

- **Industry Benchmarks**: Comparable automation projects show 1.5-2 year payback
- **Vendor Quotes**: UR5e ($35k), Robotiq ($5k), confirmed availability

1.12.2 Appendix B: Regulatory Compliance

- **Standards**: ISO 10218 (robot safety), ISO/TS 15066 (collaborative robots)
- **Certifications**: CE marking required for EU deployment (if applicable)

1.12.3 Appendix C: References

- 01_Core_Robotics_Concepts.md
- 04_Problem_Statement_IPO.md
- 05_Technical_Stack.md
- 08_High_Level_Design.md

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