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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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| **Author(s)** | Project Management Office, Business Analysis Team |
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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 │  
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┌────────────────────────────────┐  
│ Steering Committee │  
│ - CFO, COO, CTO │  
│ - Monthly reviews │  
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│ Project Manager (PM) │  
│ - Day-to-day leadership │  
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│ Tech │ │ Business │ │ Quality │ │ Support │  
│ 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)

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

**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 |
|  | - 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](./01_Core_Robotics_Concepts.md)
* [04\_Problem\_Statement\_IPO.md](./04_Problem_Statement_IPO.md)
* [05\_Technical\_Stack.md](./05_Technical_Stack.md)
* [08\_High\_Level\_Design.md](./08_High_Level_Design.md)

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