S.P.A.R.K. Crawler

Surface Preservation and Rust Killer

South Dakota
State University

Meet the Team

Alexis Smith
Mechanical Engineering
Sophomore

Teyla Hanson
Mechanical Engineering
Sophomore

Meloray Linderer
Mechanical Engineering
Sophomore

Noah Richardson
Mechanical Engineering
Sophomore

John Worth
Mechanical Engineering
Freshman

Todd Letcher
Mechanical Engineer
Advisor

Interviewing Aircraft Maintenance Professionals

Industry interviews enabled our team to identify key needs and challenges across the aviation sector. We engaged with commercial aircraft manufacturers, military maintenance personnel, and general aviation maintenance professionals to better understand current operational and maintenance concerns:

- Time-consuming tasks
  - Maintenance tasks are delaying the return of essential aircraft.
- Inspection wait times
  - Inspection wait times are delaying the finalization of a repair.
- Corrosion repair was deemed a difficult task.

Situation Assessment - Corrosion

- In the aging aviation infrastructure, corrosion is one of the leading maintenance repairs, with surface corrosion as the most common metal degeneration problem on an aircraft.

- Corrosion repair requires following strict FAA regulations and safety procedures (with appropriate PPE).

- Multiple forms of corrosion:
  - Uniform Surface
  - Filiform
  - **Pitting**

- While pitting is less common than surface corrosion, it is significantly more dangerous and destructive due to potential deep penetration if left untreated.

Current Methods

Maintenance Personnel are required to follow strict FAA regulations regarding corrosion repair.

Mandated Safety Regulations From FAA Title 14 Code of Federal Regulations (14 CFR), Parts 121, 129, 135 Operators:

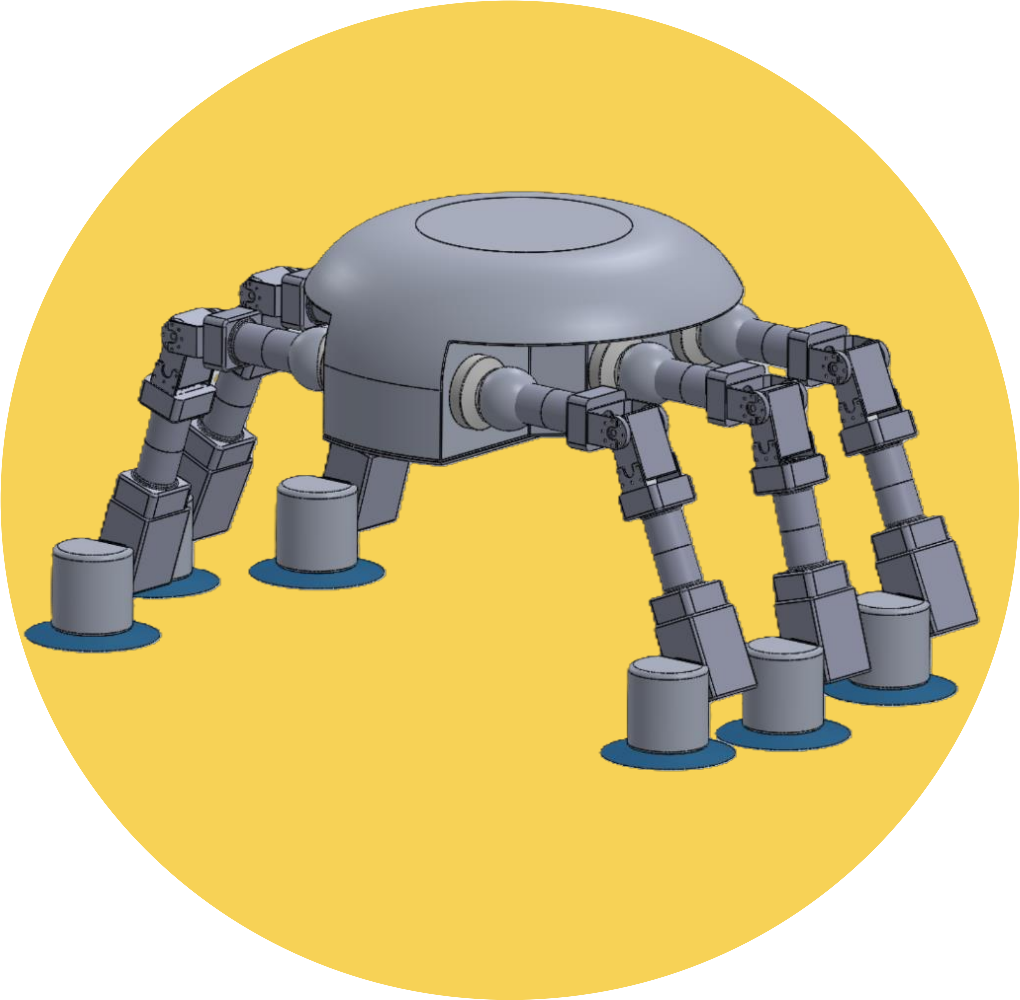
- Personal Protective Equipment (PPE) is required to shield eyes, skin, and the respiratory systems
- Decontamination showers after repair
- Documented time spent on the repair and around the repair chemicals
- Required cardiopulmonary tests every 6 to 12 months to monitor the heart and lungs

Methods for identifying corrosion:

- Visual inspections
- Dye penetration testing
- Thermal or X-Ray scanning

Design Solutions

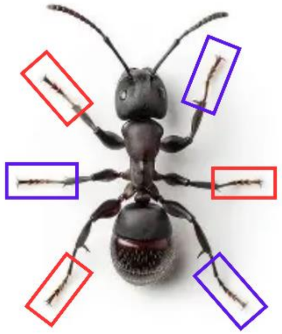
The S.P.A.R.K. Crawler (**S**urface **P**reservation **A**nd **R**ust **K**iller) is an autonomous 6-legged crawler that uses a separate thermal imaging technology to identify and locate affected areas for repair of pitting corrosion on the exterior of the aircraft. The S.P.A.R.K. Crawler uses a familiar 4-step corrosion repair process: locate, prep, treat, and paint, and an ant-like locomotion system to complete each repair.

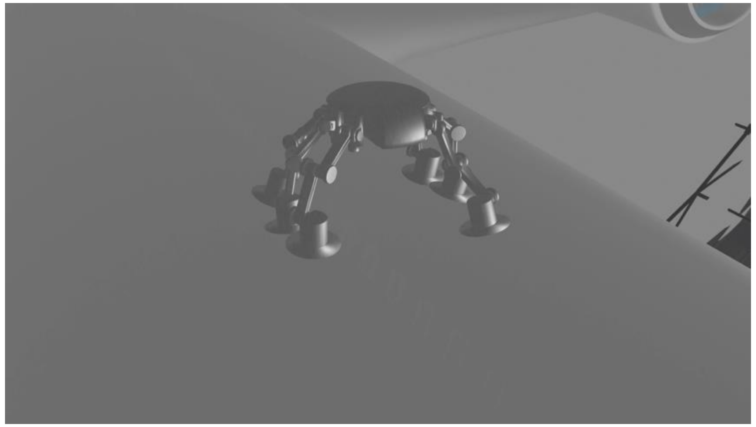


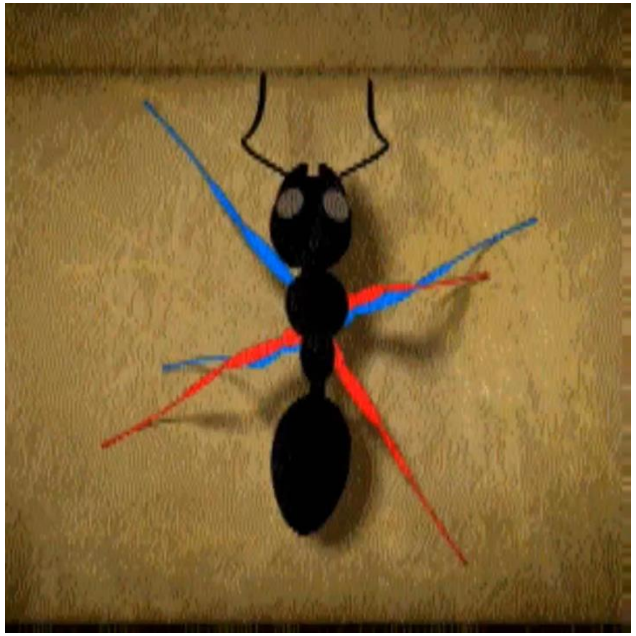
Locomotion System

The S.P.A.R.K. Crawler utilizes a six-legged, suction-cup-powered locomotion system to maneuver across aircraft surfaces. Its mobility approach is modeled after an ant's tripod gait (see colors below), maintaining three active contact legs during each movement cycle to provide stability and continuous adhesion.

The vacuum-powered suction cups enable the S.P.A.R.K. Crawler to securely adhere to the aircraft surface while operating safely and reliably.







Suction System

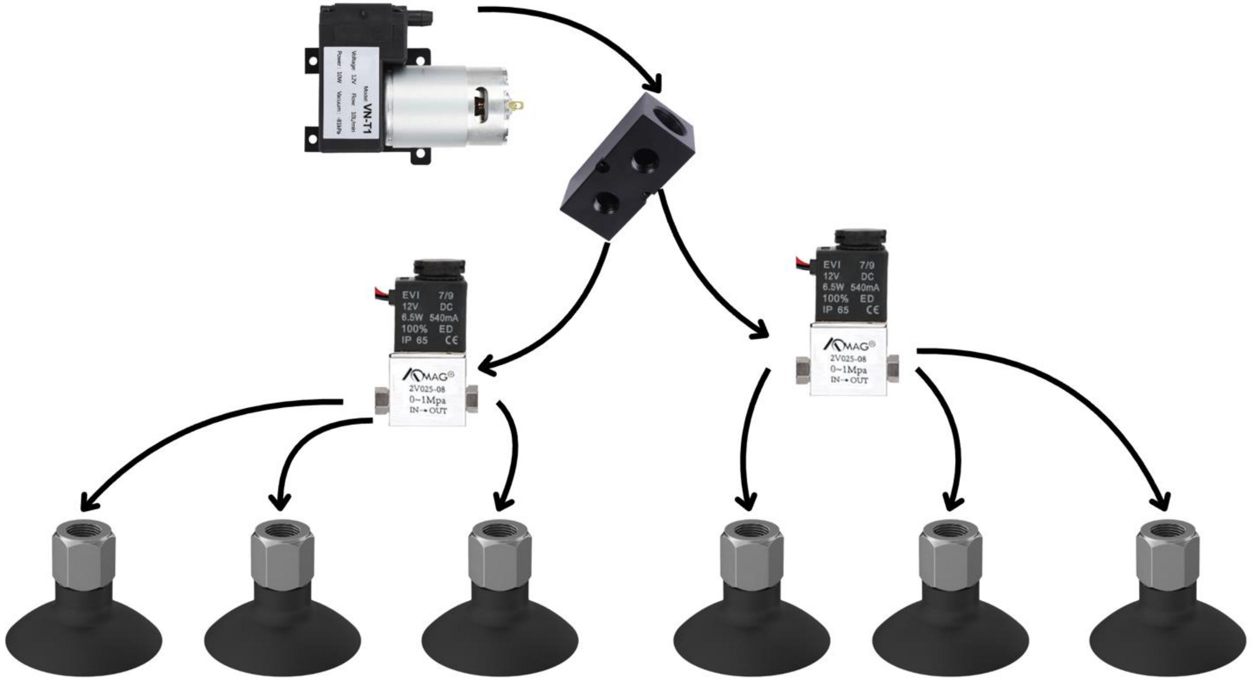
The S.P.A.R.K. Crawler utilizes a vacuum pump powered suction cup system to adhere to the side of the aircraft.

Components of the Suction cup system:

- Vacuum pump
- Manifold
- Solenoid
- Tubing Connectors
- Barbed Hose Connection
- Suction Cup

Benefits for the aircraft:

- Less damage to the paint
- Won’t interfere with electronics
- Higher FOS



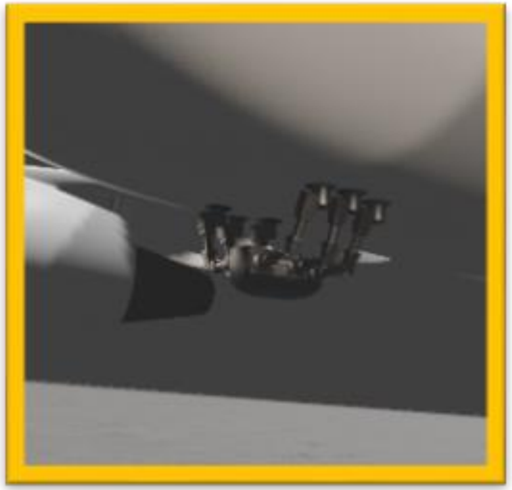
Locomotion System Safety

The suction cup system and locomotion system work in unison to provide a safe and efficient movement over the aircraft. The different states of connection are:

- Stationary – all 6 legs are connected to the airplane surface
- Walking – 3 legs are connected, 3 legs are moving
- Slipped state – 1 or 2 legs failed to attach to the surface, and S.P.A.R.K. is dangling by 1 connected leg

Number of legs	FOS
6 Legs	9.3
3 Legs	4.78
1 Leg	1.59

6 Legs



3 Legs

1 Leg

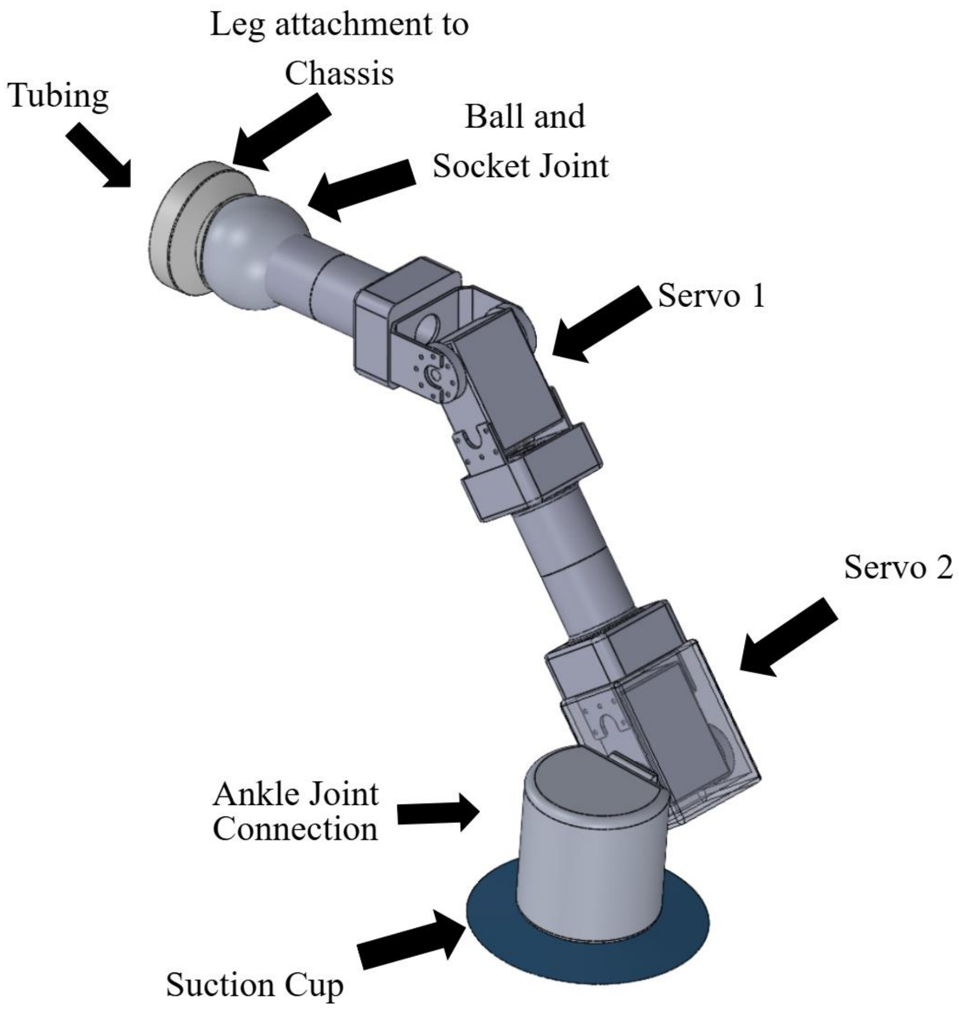
Locomotion System

The S.P.A.R.K. Crawler legs have three critical components: joints, motors, and suction cups.

Vacuum Tubing:
- Tubing runs internally on each leg
- Barbed fitting in the ankle joint

Joints:
- Each has a motor/degree of freedom
    - Knee and ankle have a 270-degree
    - Shoulder joint has a Ball and Socket Joint

Motors:
- Initial prototype uses servo motors
- Full-scale model will use BLDC motors with encoders



Repair Process

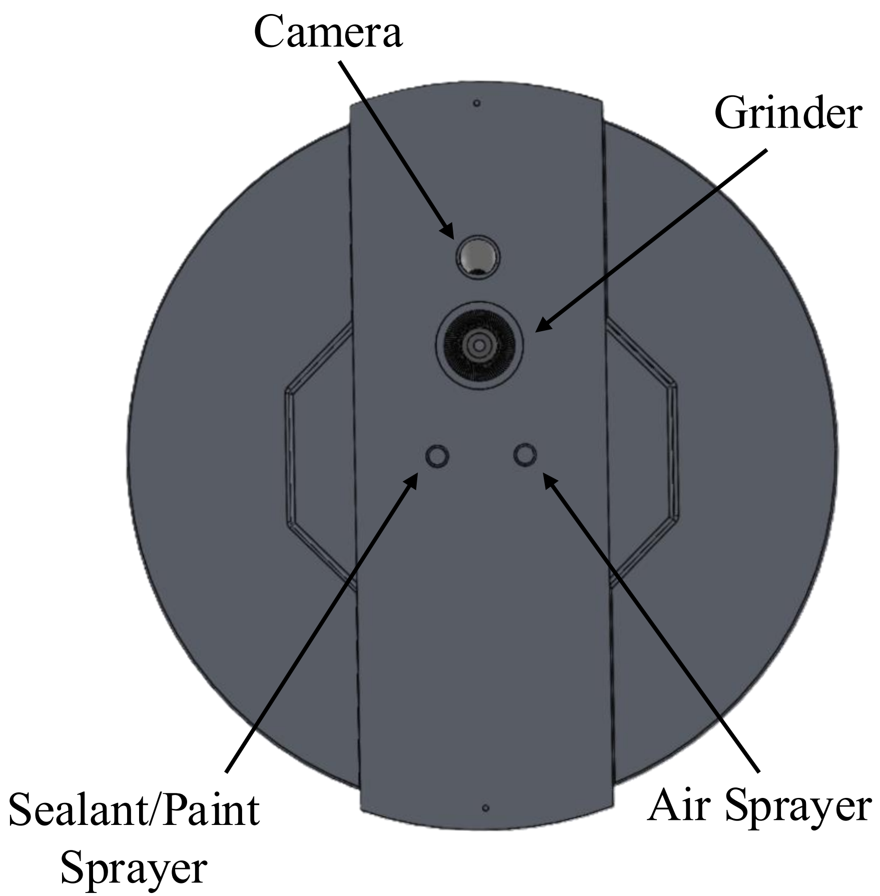
The S.P.A.R.K. Crawler corrosion repair process will include a 4-step process that utilizes autonomous tooling and monitoring systems.

Repair Process Components:

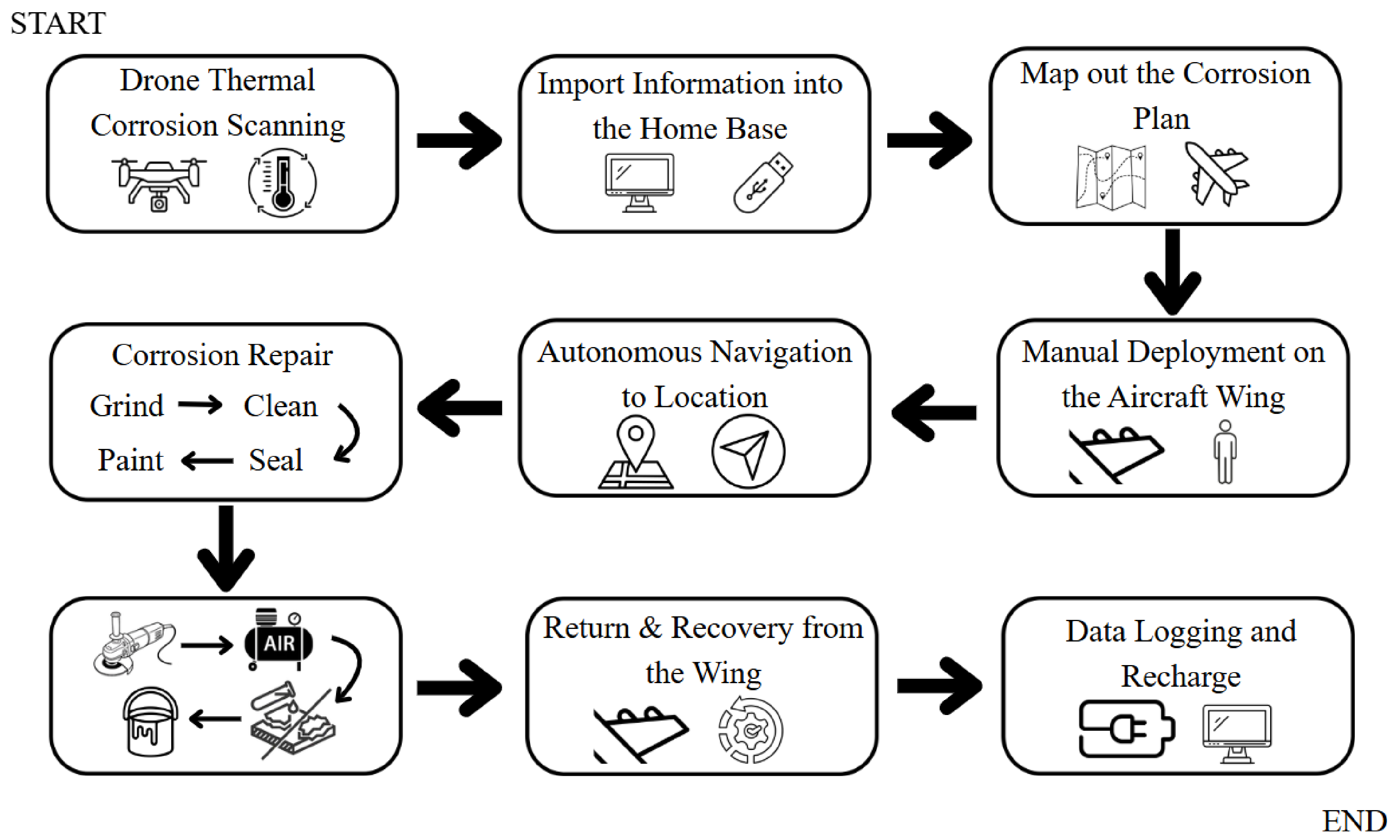
1. Grinder System
2. Compressed Air Sprayer
3. Chemical Sealant Sprayer
4. Paint Sprayer

Repair Process Steps:

- Grinds away corrosion
- Clears repair area from debris
- Sprays chemical sealants over effected area
- Reapplies paint to repair site



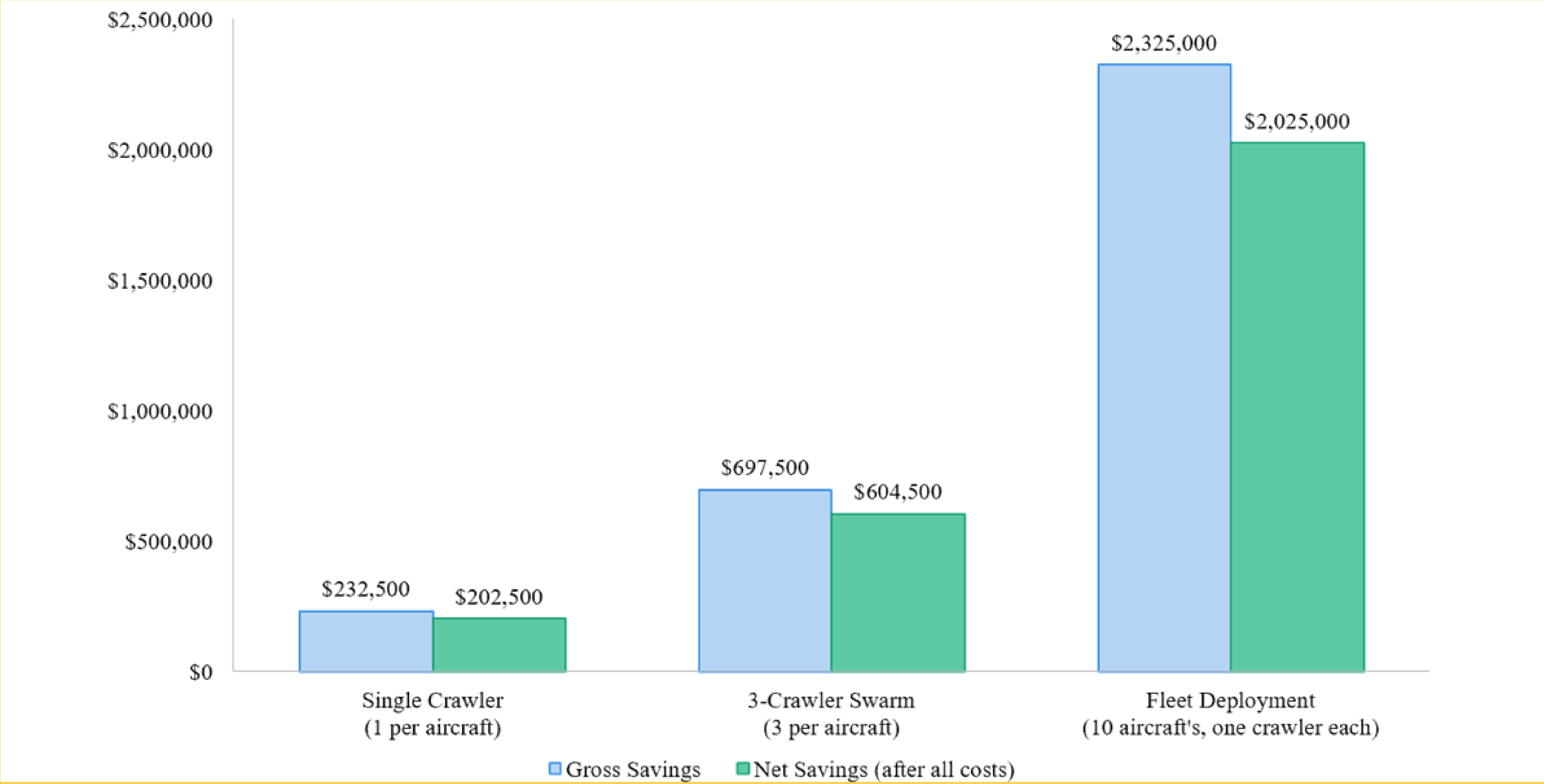
Concept of Operations



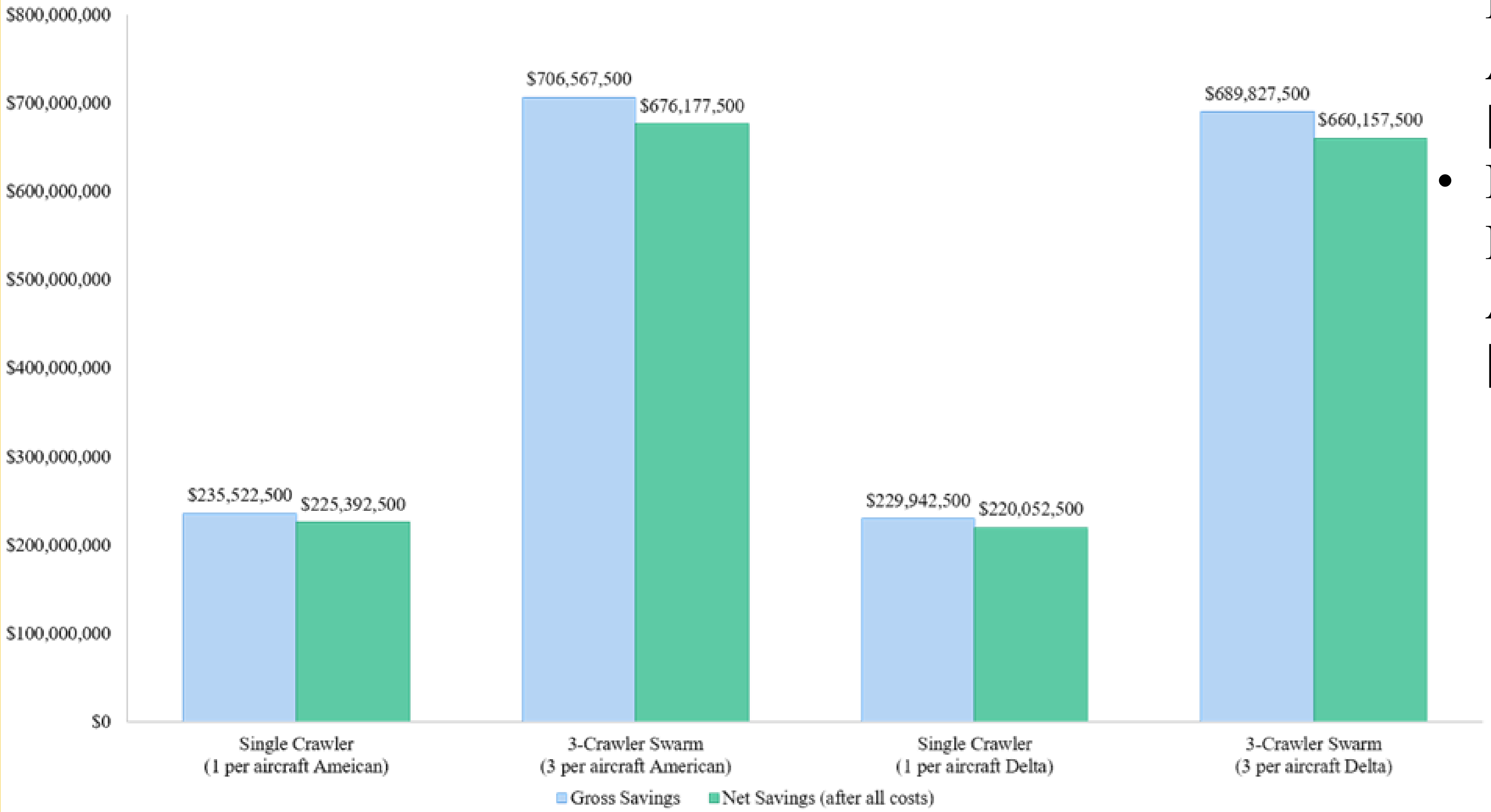
Return on Investment

Multi-Crawler & Fleet Deployment Scenarios						
Single Crawler (1 per aircraft)						
Metric	**Units**	**Year 1**	**Year 3**	**Year 5**	**Year 7**	**Year 10**
Gross savings	$	$23,250	$69,750	$116,250	$162,750	$232,500
Operating costs	$	$2,000	$6,000	$10,000	$14,000	$20,000
Net savings	$	**$11,250**	**$53,750**	**$96,250**	**$138,750**	**$202,500**
Hours returned to tech	h	310 h	930 h	1,550 h	2,170 h	3,100 h
3-Crawler Swarm (3 per aircraft)						
Metric	**Units**	**Year 1**	**Year 3**	**Year 5**	**Year 7**	**Year 10**
Gross savings	$	$69,750	$209,250	$348,750	$488,250	$697,500
Operating costs	$	$6,000	$18,000	$30,000	$42,000	$60,000
Net savings	$	**$30,750**	**$158,250**	**$285,750**	**$413,250**	**$604,500**
Hours returned to tech	h	930 h	2,790 h	4,650 h	6,510 h	9,300 h
Fleet Deployment (10 aircraft's, one crawler each)						
Metric	**Units**	**Year 1**	**Year 3**	**Year 5**	**Year 7**	**Year 10**
Gross savings	$	$232,500	$697,500	$1,162,500	$1,627,500	$2,325,000
Operating costs	$	$20,000	$60,000	$100,000	$140,000	$200,000
Net savings	$	**$112,500**	**$537,500**	**$962,500**	**$1,387,500**	**$2,025,000**
Hours returned to tech	h	3,100 h	9,300 h	15,500 h	21,700 h	31,000 h

Return on Investment After 10 Years

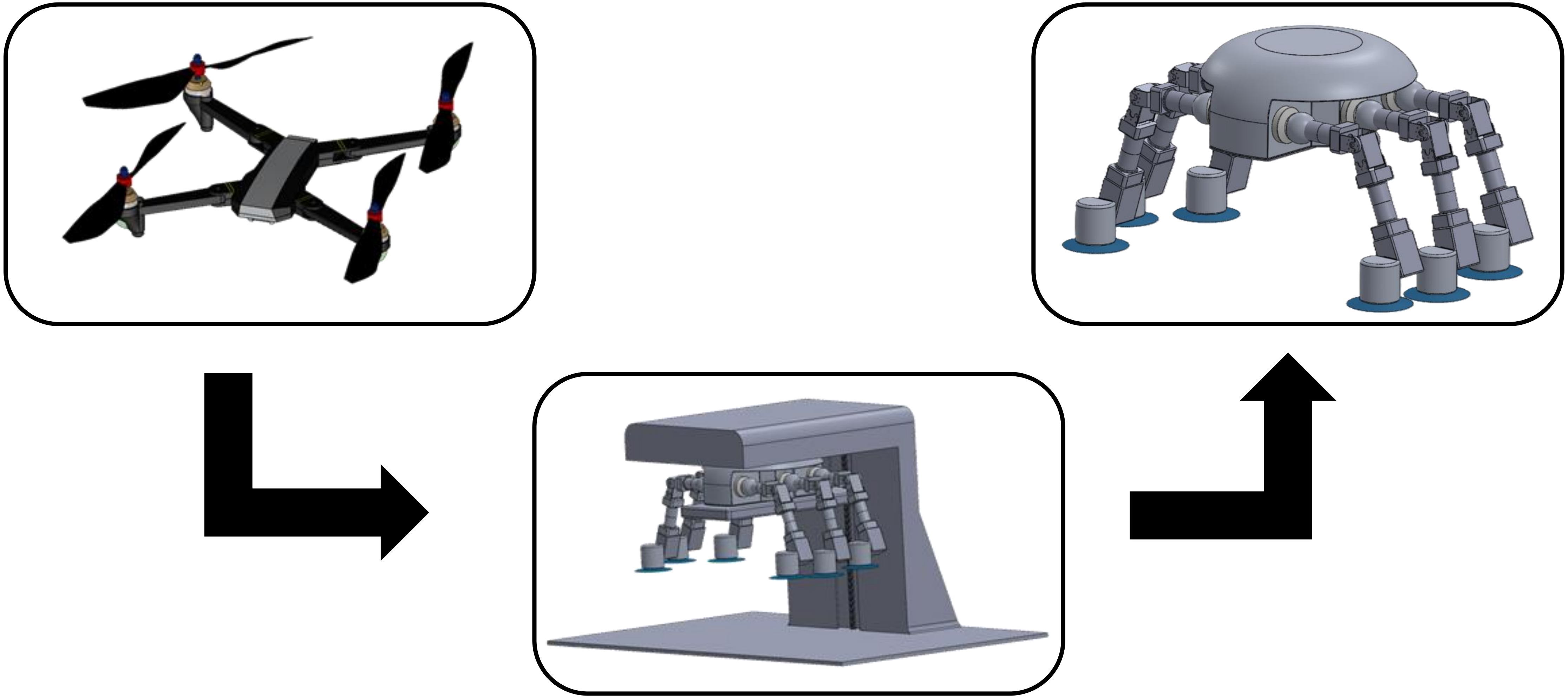


ROI on a Significantly Larger Scale



- American Airlines Fleet size: **1,013** Active Aircraft [1]
- Delta Air Lines Fleet size: **989** Active Aircraft [1]

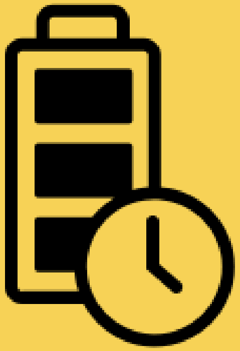
Connectivity Constraints



Operation Constraints

Dirty Aircraft

Fluid tank capacity



Battery Life

Dirty aircraft can affect the success of the suction cups

The fluid tank capacity will determine the number of repairs

The battery life will determine the length of which the crawler is operational

Timeline to Deployment

2026: Alpha Model of the S.P.A.R.K. Crawler and suction-walking testing.
Expected TRL:3

2027: Start chassis testing and start development of the Beta Model.
Expected TRL:4

2028: Spot corrosion testing and paint & sealant testing for the Beta Model.
Expected TRL:5/6

2029: FAA approval process and initial marketing of the S.P.A.R.K. Crawler.
Expected TRL: 7

2030: Continued marketing of the Pitting crawler. Begin developing the Alpha Model of the S.P.A.R.K. crawler for filiform corrosion.
Expected TRL: 4

2031: Continue suction-walking testing and chassis testing for Filiform crawler.
Expected TRL: 5

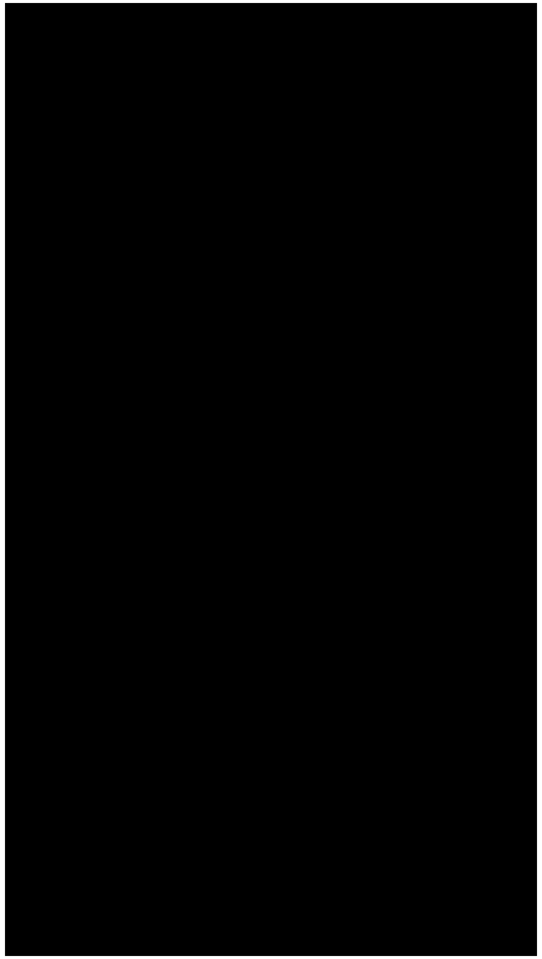
2032: Filiform spot corrosion testing, along with paint & sealant testing.
Expected TRL: 6

2033: FAA approval for this version and initial marketing for filiform S.P.A.R.K. crawler and start production
Expected TRL: 7

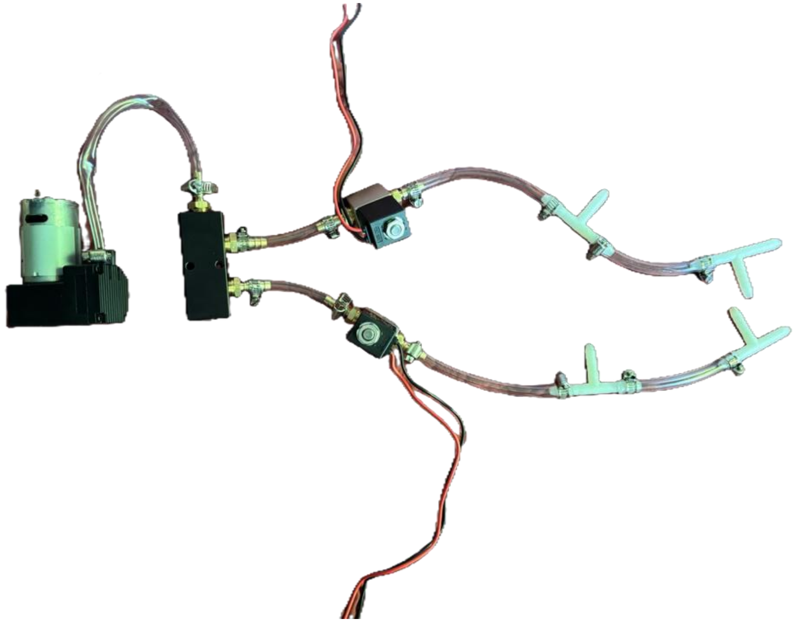
2034: Scale production of both S.P.A.R.K. crawlers of the newest models.
Expected TRL: 8

2035: Continue designing the S.P.A.R.K. crawler for different types of corrosion.
Expected TRL: 7

Prototype



1st Leg Prototype

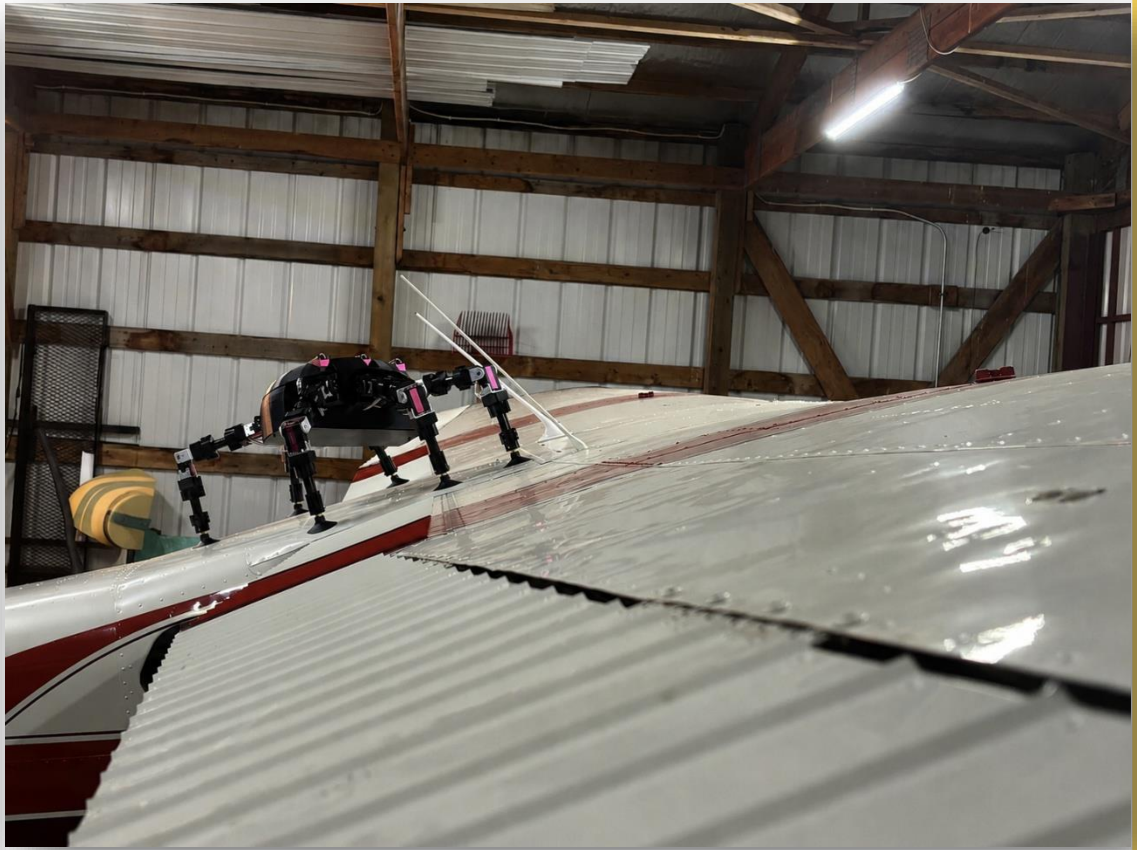


Internal Vacuum Pump System

Prototype leg

Prototype

Prototype



References

- https://www.maaero.com/a-complete-guide-to-the-types-of-corrosion-in-aircraft/
- https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/1034449
- Largest Airlines in the World by Fleet Size in 2026 - Aviation A2Z

Questions


S.P.
Surface
Team Members: Teyla
Grinds off
corrosion & paint
Barbed
Hose
Suction
Cup
Composition

Backup Slides

S.P.A.R.K. Crawler — Model Assumptions & Inputs		
Parameter	**Value**	**Notes / Source**
Labor		
Labor rate — low ($/hr)	**65.00**	*Source: Industry avg, FAA MRO survey 2023*
Labor rate — high ($/hr)	**85.00**	*Source: Industry avg, FAA MRO survey 2023*
Labor rate — avg ($/hr)	$75.00	*Midpoint used in all calculations*
Maintenance Cycles		
Corrosion maintenance cycles / yr / aircraft	**5.00**	*Typical commercial operator; adjust as needed*
Unit Costs		
Gen-1 unit cost — low ($)	**$9,000.00**	*Production-scale estimate*
Gen-1 unit cost — high ($)	**$10,000.00**	*Production-scale estimate*
Gen-2 unit cost — low ($)	**$11,500.00**	*Expanded sensing + tooling*
Gen-2 unit cost — high ($)	**$13,000.00**	*Expanded sensing + tooling*
Operating Costs		
Annual operating cost — low ($/unit/yr)	**$1,600.00**	*Consumables, servicing, parts*
Annual operating cost — high ($/unit/yr)	**$2,000.00**	*Consumables, servicing, parts*
Annual operating cost — avg ($/unit/yr)	$800.00	*Used in lifecycle tables*
System Oversight		
Technician oversight hours / yr / aircraft	**24.00**	*Setup + supervisory time (not counted as savings)*
Downtime Value		
Aircraft downtime cost ($/hr)	**$10,000.00**	*Source: Commercial aviation ops, ref [11]*
Downtime hours saved / maintenance cycle	**2.00**	*Conservative estimate vs. manual AOG extension*

Backup Slides

Task-by-Task Time & Cost Breakdown (Per Aircraft / Year)						
Maintenance Task	**Manual (h/yr)**	**S.P.A.R.K. (h/yr)**	**Hours Saved**	**Cost Saved ($/yr)**	**% Reduction**	**Automation Method**
Surface inspection & scanning	80 h	8 h	72 h	$5,400	90.0%	**Autonomous**
Abrasive corrosion removal	120 h	12 h	108 h	$8,100	90.0%	**Autonomous**
Sealant & primer application	60 h	6 h	54 h	$4,050	90.0%	**Autonomous**
Paint restoration	80 h	4 h	76 h	$5,700	95.0%	**Autonomous**
System setup & oversight	0 h	24 h	—	—	—	**Technician**
TOTAL (automated tasks only)	**340 h**	**30 h**	**310 h**	**$23,250**	**91.2%**	

Backup Slides

Single Crawler — Lifecycle ROI (Per Aircraft)						
Metric	**Year 1**	**Year 2**	**Year 3**	**Year 5**	**Year 7**	**Year 10**
Gross savings ($)	$23,250	$46,500	$69,750	$116,250	$162,750	$232,500
Annual operating cost ($)	$2,000	$4,000	$6,000	$10,000	$14,000	$20,000
Net savings — annual ($)	$21,250	$42,500	$63,750	$106,250	$148,750	$212,500
Cumulative gross savings ($)	**$23,250**	**$46,500**	**$69,750**	**$116,250**	**$162,750**	**$232,500**
Cumulative operating costs ($)	**$2,000**	**$4,000**	**$6,000**	**$10,000**	**$14,000**	**$20,000**
Cumulative net savings ($)	**$11,250**	**$32,500**	**$53,750**	**$96,250**	**$138,750**	**$202,500**
Hours returned to technician	310 h	620 h	930 h	1,550 h	2,170 h	3,100 h
Cumulative hours returned	**310 h**	**620 h**	**930 h**	**1,550 h**	**2,170 h**	**3,100 h**

Backup Slides

Unit Cost & Lifecycle Ownership Cost			
Item	**Gen-1 (Pitting)**	**Gen-2 (Filiform)**	**Notes**
Unit cost — low	-	$10,000	*Production-scale COTS*
Unit cost — high	$9,000	$11,500	*Production-scale COTS*
Annual operating cost	$2,000	$2,000	*Consumables + servicing*
5-yr total cost of ownership	$10,000	$20,000	*Low unit + 5yr ops*
10-yr total cost of ownership	$20,000	$30,000	*Low unit + 10yr ops*
Projected lifespan	5–10 years	5–10 years	*Routine deployment*
30–40% cost reduction vs prototype	Yes	Yes	*Bulk procurement + reuse*

Backup Slides

This is for the worst-case scenario, walking across the underbelly of an aircraft.

$$W = 35\,kg \times 9.81\,\frac{m}{s^2} = 343.35\,N$$

$$F_{required} = W \times FOS_{min} = 1030.05\,N$$

$$A = \pi\left(\frac{0.1524\,m}{2}\right)^2 = 0.0182\,m^2$$

$$F_{cup} = eff \times Active\ Vacuum \times A = 547.244\,N$$

$$F_{cup} \times 6 = 3283.46\,N = F_{Allcups}$$

$$FOS_{eff} = {F_{Allcups}}/{W} = 9.56$$

Unloading 3 cups to walk across the underbelly of the aircraft

$$F_{walking} = F_{cup} \times 3 = 1641.732\,N$$

$$FOS_{walking} = {F_{walking}}/{W} = 4.781$$

If one of the three cups fails while walking, and only two are holding on at a time per side

$$F_{cupfailure} = F_{cup} \times 2 = 1098.488\,N$$

$$FOS_{cupfailure} = {F_{cupfailure}}/{W} = 3.187$$

For critical failure if all but one leg fails

$$F_{CupCritical} = F_{cup} = 343.35\,N$$

$$FOS_{Critical} = {F_{cup}}/{W} = 1.59$$

Assumptions:

- Crawler Mass (Fully loaded up) ≈ 35 kg
- $FOS_{min} = 3$
- Suction Cup Diameter = 0.1524 m (6 in)
- Suction efficiency = 50%
- Active Vacuum = -60 kPa