IMPLEMENTATION PLAN AND PROJECT PROPOSAL Version 1/23/2015	LRRB INV #: SP&R #: ARTS Project #:

TITLE OF PROJECT:

Improving Quality of Bridge Inspections Using Unmanned Aircraft Systems

PROJECT PROPOSED BY: Jennifer Zink
State Bridge Inspection Engineer, Bridge Office

TOTAL BUDGET $ 100,000		**OVERALL PROJECT SCHEDULE**
SOURCE	AMOUNT	
MnDOT State Research Funds…	$	DATE PLAN COMPLETED: March 2016
Office or District Funds………..	$	**(allow time for review, approval and contract process)**
Federal SP&R………(__%)	$	PROJECT START DATE: July 1 , 2016
LRRB……………………………	$	PROJECT LENGTH (MONTHS): 24
Other:___________________	$	

PROJECT OVERVIEW AND GOALS

The increasing costs of bridge inspections are a concern for the Minnesota Department of Transportation (MnDOT). The use of Unmanned Aircraft Systems (UAS) may help alleviate these costs and improve the quality of bridge inspections. The UAS can deploy a wide range of imaging technologies including high def still, video, and infrared sensors, and 3D imaging software.

Utilizing UAS technology, MnDOT completed a small research project in 2015 to study the effectiveness of UAS technology applied to bridge safety inspections for both state and local bridges. The project team inspected four bridges at various locations throughout Minnesota and evaluated the UAS's effectiveness in improving inspection quality and inspector safety based on field results. A second research effort demonstrated UAS imaging on the Blatnik Bridge and to investigate UAS use in confined space inspections, project and inspection planning, and emergency response to bridge hits when it is deemed unsafe for inspectors and traditional access methods to be deployed. Additionally, a best practices document will be created to identify bridges that are best suited for UAS inspection based on bridge type, location, condition, and other variables. This effort is scheduled to conclude on June 30, 2016.

It is the goal, based on this research; to implement a statewide UAS bridge inspection contract which will identify overall cost effectiveness, improvements in quality and safety, and future funding sources for both state and local bridges.

MnDOT PROJECT MANAGER OR TECHNICAL LIAISON

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APPROVALS

OFFICE DIRECTOR OR DISTRICT ENGINEER Office or District: Bridge Office I hereby certify sufficient staff time will be scheduled for the Project Manager and staff to complete the project as outlined in the attached work plan, and commit any Office or District funds as listed above.	Signature of Office Director or District Engineer: ______________________________ Kevin Western Date:
DIRECTOR OF RESEARCH SERVICES SECTION Approval of work plan and any MnDOT State Research Program funds as listed above.	Signature of the Director of Research Services: ______________________________ Linda Taylor Date:

IMPLEMENTATION PLAN AND PROJECT PROPOSAL

INNOVATION ROADMAP INFORMATION

1) What are the expected benefits to MnDOT from implementing the results of the project? What is the impact on the department?

The use of Unmanned Aircraft Systems (UAS) may help alleviate inspection costs, improve the quality of bridge inspections, reduce the duration of traffic impacts due to the use of conventional inspection equipment and alleviate potential safety hazards bridge inspectors typically encounter.

From the current research, a cost comparison between UAS inspection and traditional inspection access methods showed that time and cost savings can be significant - up to 66%. UASs also provide inspection detail from still images, video, infrared images, and 3D modeling that effectively replicates detail learned by traditional access methods without traffic control, which increases safety. UAS inspection additionally provides access to bridge elements not readily or consistently viewed up close.

- Decrease Engineering/Administrative Costs (Planning/design costs, paperwork)
- Environmental Aspects (Pollution, hazardous waste reductions, recycling)
- Safety (Reduction of crash frequency and/or severity)
- Technology (Technology transfer, new materials, new methods)
- Road User Benefits (Time, dollars)

During the UAS research project, the inspection needs of the approach spans of a large bridge were used for a sample calculation of time/cost savings given equipment and personnel needed for inspection. Based on the traditional methods of inspection, this bridge would typically utilize three snoopers (inspection vehicles) and require eight total inspection days. This equates to a minimum cost for that inspection using conventional equipment of approximately $59,000 (does not include equipment mobilization and travel expenses). The cost of a UAS contract to inspect all of these same approach spans of this sample bridge would be around $20,000 with only 5 days onsite. This is a potential cost savings of 66%.

UASs also provide inspection detail from still images, video, infrared images, and 3D modeling that effectively replicates detail learned by traditional access methods without traffic control, which increases safety. The infrared and 3D modeling detail of bridges through UAS, effectively identifies concrete delamination, gathers topographic mapping detail and efficiently maps riverbank conditions upstream and downstream from the bridge site.

UAS inspection additionally provides access to bridge elements not readily or consistently viewed up close.

Lastly, UASs are lightweight and run on battery power; therefore, they have no impact to the environment.

2) What transportation problem is this project solving? What has been attempted in the past to solve this problem and what remains to be solved?

Timely bridge inspection is the critical first step in keeping bridges safe and in good driving condition. MnDOT inspects every bridge in its system at least once every 24 months, with fracture-critical bridges (where failure of a single component could cause collapse) receiving reviews every 12 months. Small bridges can be inspected in a day, but large bridges can take weeks to fully inspect. With more than 20,000 bridges and 600 bridge inspectors statewide, the task proves more than just a logistical challenge.

Because the core of bridge inspection is visual review, inspectors are often put in physically challenging situations in order to access all the bridge components. They may need to utilize rope climbing gear or climb into the buckets of under-bridge inspection vehicles: articulated cranes that reach from the bridge deck surface over the edge of the bridge to the underside. These “snooper” trucks cost about $750,000 to buy, and present expenses for fuel, training, maintenance and on-bridge traffic control. An inspection-specific UAS costs around $40,000.

Fortunately, the new technology of unmanned aerial vehicles may reduce some of this expense as well as the safety risk to inspectors. Camera-equipped unmanned aerial systems can be flown beneath bridge decks to capture images or video footage of bridge elements quickly and efficiently with limited impact on traffic at a significantly lower cost. UASs offer promise for bridge inspection, but MnDOT had not conducted formal research to evaluate such applications until recently.

3) Additional information about the project and goals:

A second research effort is currently underway at MnDOT to also investigate UAS use in regards to confined space inspections, project and inspection planning, and emergency response to bridge hits when it is deemed unsafe for inspectors and traditional access methods to be deployed. This effort is scheduled to conclude on June 30, 2016.

It is the goal, based on this research; to implement a statewide UAS bridge inspection contract which will identify overall cost effectiveness, improvements in quality and safety, and future funding sources for both state and local bridges.

4) How does the proposed project build upon previous research? If further research is proposed, why does similar previous research not solve the Minnesota transportation problem being addressed and why is further research needed?

Prior to MnDOT's 2015 research on UAS use in bridge inspection, no other transportation entity in the nation had explored this as an option. A number of years back, Caltrans started a potential project on investigating UASs in bridge inspection, but nothing came from that as the UAS would not fly. Since then, UAS technology has greatly advanced. Even now, between MnDOT's Phase I (2015) and Phase II (2015/2016) projects, an inspection-specific UAS was not available (and only as a prototype) until Phase II.

For Phase I, an Aeyron Skyranger UAS (Skyranger) was used. While the Skyranger met many of the requirements for collecting inspection data, its range of vision prevented views of objects directly above it. In addition, at the time of the study, the Skyranger was unable to fly directly under the bridge decks. Doing so would cause it to lose the GPS signal and the aircraft would attempt to return to the launch point by flying vertically, which was problematic with a bridge deck overhead. The final report is located at: http://www.dot.state.mn.us/research/TS/2015/201540.pdf.

Phase II of this study—currently in progress—is exploring technology that is specifically built for performing inspections, with a forward and upward facing camera head and the ability to fly directly under the bridge deck. Using the Sensefly eXom , the preliminary results have been very positive. The eXom has several inspection-specific features including the ability to provide an upward view, the ability to fly without GPS, an integrated thermal camera, and ultrasonic sensors for obstacle avoidance. These features proved very valuable when performing inspections. The flight time is around twenty minutes at which time the battery can be exchanged for a freshly charged one.

However, overall performance and benefits of utilizing an inspection-specific UAS at a state-wide level is yet to be determined. The preliminary results of our research show the benefits of using a UAS as a bridge inspection tool are clear and the advances in technology have increased the potential for long term implementation. UAS's should be considered in situations where the safety and the quality of the inspections can be improved.

5) How will the results of the completed project be put into practice and deployed by MnDOT? Who needs to make a formal decision to implement and deploy, and who would be responsible for implementation and deployment?

The ultimate goal at the conclusion of this research is to identify bridges that UAS inspection could provide the close detail necessary for a thorough inspection. Currently at the MnDOT Bridge Office, we are attempting to initiate a policy for bridges that meet certain condition criteria (i.e. poor) that will require close-up inspection at an interval of every 5 years. The access requirements could potentially be very costly to meet this policy, especially for local agencies. We anticipate that inspection by UAS can alleviate a lot of these costs. The idea would be to implement a state-wide UAS contract to obtain close-up inspection data for all bridges meeting the criteria of this policy on a 4 year cycle...for both state-owned and locally owned bridges. The details of this in regards to funding and state aid involvement will be addressed at the conclusion of the Phase II study.

Formal decisions regarding this project are designated to:
Kevin Western - MN State Bridge Engineer - and State Aid will make the formal decision to implement and deploy.
Jennifer Zink - MN State Bridge Inspection Engineer - will be responsible for implementation and deployment.

The project will develop the following end-user products:

- Manual, Handbook, Field Guide - inspections by UAS, including best practices and a decision tree as to which bridges are more preferable to UAS inspection, will be included in the Minnesota Bridge and Structure Inspection Program Manual
- Best Practices Guidance - see above
- Test or Inspection Method - method of inspection by UAS will be outlined and described

- Decision Making Process or Framework - a decision tree will be created to guide bridge owners as to which bridges will benefit from UAS inspection
- Modify or Implement a Policy - implement policy on inspection access requirements in regards to bridges in poor condition; UAS inspection will be a cost effective access option in this case
- Streamlining or Automation - inspection by UAS as opposed to traditional access methods will streamline the amount of inspection time required; this data will be captured and compared per Phase II and this implementation project
- Streamlining or Automation – streamlining of the FAA / MnDOT Aeronautics permit and approval process
- Energy Efficiency - UAS inspection is environmentally friendly; no exhaust or impact to traffic, environment or wildlife as opposed to under-bridge inspection vehicles
- Asset Management System or Supporting Data - imagery data obtained from UAS inspection will be incorporated (uploaded) into the Minnesota Structure Information Management System (SIMS) as part of the "living" bridge file
- Decision Support System - see Decision Making Process comments

Technical advisory panel or project steering committee:

- Kevin Western - MnDOT State Bridge Engineer
- Ed Lutgen - MnDOT Bridge Construction and Maintenance Engineer
- Bruce Holdhusen - MnDOT Research Services
- Scott Theisen - MnDOT Fracture Critical Bridge Inspector
- Dave Conkel - Bridge State Aid
- Tara Kalar - MnDOT Office of Chief Counsel
- Richard Braunig - MnDOT Office of Aeronautics
- District Bridge Engineers x 1 representative
- Local Bridge Engineers x 1 representative
- UAS Consultant

MnDOT specialty offices:

- Bridge,
- Aeronautics,
- State Aid
- Office of Chief Counsel

MnDOT Districts and District functional groups:

- All MnDOT District Bridge Engineers based on bridge inspection location...

Additional key practitioners or management champions:

Management group:

- BMT - Bridge Management Team;
- BMS - Bridge Maintenance Supervisors,
- others as determined by project champion
- ...informed by Jennifer Zink and Ed Lutgen

Practitioner committee:

- District Bridge Engineers ...informed by Jennifer Zink and Ed Lutgen

Other cooperating program or agency:

- WisDOT/NDDOT (for border bridges);
- APWA Local Chapter

Other stakeholders:

- Public;
- Media
- Local Road Research Board

Others who may be interested, not listed above:

- Other state DOTs,
- Local Road Research Board

- researchers,
- universities,
- foreign countries...

MnIT involvement (software, data management, or technology devices):

- No software, data management or technology devices that require coordination with MnIT.
- Electronic storage of images and video may be a long-term issue

Items for State contract or Approved Products list:

- A State contract for UAS bridge inspection services work orders would be developed

Intellectual Property or licensing:

None

6) What future efforts or steps will be needed to derive full benefits from the expected results of this project?

MnDOT is committed to the following future steps:

- Identify frequency of UAS inspection cycle.
- Identify funding for long-term implementation - State Aid will need to be involved as this will include local agency bridges.
- Finalize in-depth bridge access policy for publishing in the Minnesota Bridge and Structure Inspection Program Manual (BSIPM)
- Revise BSIPM chapters in regards to UAS inspection requirements and best practices.
- Determine if it is more cost effective for MnDOT to purchase their own UAS fleet as opposed to contracting.
- During Phase II and through this implementation project, a state-wide list will be determined for bridges that prove favorable to UAS inspection based on the in-depth bridge inspection access policy. This "living" list will be published and obtainable to all bridge owners through the MnDOT Bridge Office website based on their bridge inventory.

7) Communication Plan

Catch phrase for marketing: **Send in the Drones**

Target audience for early communication (in addition to those named above):

- Bridge Office - steering committee designated in a previous section
- Office of Aeronautics - Rick Braunig
- Office of Chief Counsel - Tara Kalar
- Consultant

Early Communication plan:

Once approved for implementation, a meeting appointment (kick-off meeting) will be sent out to the target audience with applicable information to the project which includes: schedule, potential bridge inspection list, and expected deliverables. All initiated communication will be the responsibility of the Project Manager - Jennifer Zink. Subsequent meetings will be scheduled as needed to update the target audience on progress. Between meetings, e-mail exchange will suffice.

- Small group discussions
- One-on-one meetings
- Email exchange

Target audience for rolling out the innovation:

- The customers identified for this project include the traveling public, public agencies as well as private consultant bridge inspectors, and taxpayers in the state of Minnesota.

Roll-out message, methods and activities:

Overall Message (to be delivered by the Project Manager):

- "The benefits of using a UAS as a bridge inspection tool are clear and the advances in technology have increased the potential for implementation. UAS's should be considered in situations where the safety and the quality of the inspections can be improved. This project challenges the status quo in regards to traditional bridge inspection access methods and data gathering. The use of UASs commercially is a very new and up-and-coming venue.

Advancements in UAS technology is growing daily, making implementation as a tool for bridge inspections a reality. Future advancements will only serve to increase the applications and effectiveness for inspections and the civil engineering field in general."

- Convincing points would be: cost comparison data overall from each bridge inspection done via UAS vs. traditional access methods, UAS data collection (imagery) comparison to bridge inspection report data, UAS infrared image comparison to that of hand-held infrared cameras and bridge deck chain dragging, and safety analysis comparison between UAS inspection vs. traditional access methods.

Roll-out timing and responsibilities:

- Phase I and II research has already been presented at many conferences and will continue to be presented. It is anticipated that the end-product will also be of interest to many conference venues.
- Some examples include: the International Bridge Conference (June), American Public Works Association (APWA - August), American Society of Civil Engineers (ASCE - September), Minnesota Transportation Conference (March), Minnesota Bridge Workers Safety Conference (April), Bridge Maintenance Supervisors Meeting (April/October), Mid-America Association of State Transportation Officials (August), etc.
- The Project Manager - Jennifer Zink - and the consultant will initiate and conduct this communication and roll-out activities.
- Help to market/communicate this project will be needed by the MnDOT Bridge Office and the Office of Communication...especially in regards to any media event.
- Meetings/conferences in regards to bridge happen any time during the year; however, most happen in the months of February through April (see months designated by conference in previous question). Lead time to arrange these methods can take anywhere of a week or two up to two months or longer - it depends on the method.
- Presentation to a conference
- Presentation to a technical group
- Internal office meeting
- Email blast
- Web site
- Powerpoint slide show
- MnDOT 'Newsline' article
- Research Services social media blast
- Demonstrations
- Brochure or one-pager
- Poster or display booth

NOTE TO USERS: It is usually not practical to use research funds to pay MnDOT salaries, except for projects using SP&R or LRRB funds where personnel from the Office of Materials and Road Research serve as the principal investigator. Contact MnDOT Research Services Section for additional information.

Additional information about funding eligibility for the Implementation Program:

1. **Address Problem or Need**
   The proposal needs to clearly state the transportation problem being solved or need that is being satisfied
2. **Research Link**
   The Implementation proposal must include a reference link to a national, state or local research project that has been completed. If the reference link is not provided, this could reduce SP&R participation. Examples of research can be linked to any of the following federal, state or local programs:
   a. Federal Program
      i. NCHRP project or other Federal Cooperative Research Programs
      ii. Pooled Fund Project (MnDOT lead, MnDOT participation in pooled fund project/program, or single state project)
   b. State Research
      i. MnDOT Research Project
      ii. Other State DOT Research Project
      iii. Intelligent Transportation System (ITS) Inst. or MN Guidestar Program
      iv. MnDOT's Maintenance New Technology Research and Equipment Committee (NTREC) program
      v. MnDOT's Cold Weather Test Facility - (MnROAD)
   c. Local Research
      i. Local Road Research Board (LRRB) research projects
3. **Demonstrate Application for department**
   The proposal needs to indicate how the results of the implementation project will be used or applied within the department. If possible, state how the results could lead to full implementation in day-to-day practice and whether there is commitment to support implementation statewide
4. **Internal Champion –** implementation proposals must identify a MnDOT staff person as the champion to move forward for funding consideration.
5. **Other Considerations:**
   Equipment purchases
   a. Should be kept to a minimum and only include items necessary to support the implementation project.
   b. Can be used as seed money to demonstrate the viability of the equipment. Pilot project proposed should be limited to a specific area or location.
   c. Not intended as a funding source for full deployment of equipment through the state.
   d. Can't be used to supplement equipment budget.
   Construction Project
   e. Extremely difficult to use research dollars to fund construction projects.

PROJECT WORK PLAN INFORMATION

BACKGROUND: Include any background information or history pertinent to the project that has not been provided above.
The only regulatory requirements for this project come from the FAA and MnDOT Aeronautics. More specific information can be found on the FAA's website, but generally, the following requirements must be met for this work:
• An approved Section 333 Exemption must be obtained.
• A licensed pilot is required.
• Flights must be line-of-sight only.
• Aircraft must be operated outside of an airport's five-mile radius unless permission is granted from the airport.
• All aircraft must be certified and registered by the FAA.
However, all of these requirements were met by the Bridge Office and Phase I and II consultant.

Contractor's inspections will be performed in accordance with the following: -"Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges" Federal Highway Administration (FHWA) Report No. FHWA-PD-96-001 (1995), including 2003/2004 errata. -Bridge Inspector's Reference Manual (BIRM), dated February 2012, FHWA National Highway Institute (NHI) 12-049 -Code of Federal Regulations, 23 CFR Part 650, Subpart C, National Bridge Inspection Standards. -Minnesota Bridge and Structure Inspection Program Manual (2016)

SCOPE: Briefly summarize the scope of work of this project. This includes an overall description of how the project will be conducted. Please summarize coordination with other projects or other work that is necessary for completion of this project, such as specialized help or input including data, materials, equipment, facilities, etc.

- Scope: Perform UAS imaging in conjunction with regular scheduled bridge inspection, finalize guidance, document project in a published final report.
- Project Duration - 24 month maximum (July 1, 2016 - or when funds become available - to June 30, 2018)
- Project Budget: at least $100,000; more funds would allow more bridges to be inspected. Estimated budget and schedule based on the UAS Phase II research cost and duration.
- No equipment necessary. The UAS will be provided for use by the consultant.
- Procurement: Pre-Qualification List - based on previous research done in Phase I and Phase II (Barritt Lovelace, P.E. - Collins Engineers)

TASKS: List the major tasks in the sequence necessary to complete the project, including the elements listed below.

Scope: For each task, give a task title, describe the work that will be included the in task and who will perform the work (consultants, contractors, university researchers, MnDOT personnel, or others). Purchase orders for equipment can be included here as a task to be completed by MnDOT. For each task there should be at least one deliverable, such as a report, test results, equipment, software, etc.

Schedule: Indicate a realistic duration for each task, and proposed start and end dates. The contract execution date will be unknown at the time this work plan is prepared, so it is important to note any "hard schedule" requirements for task start or ending dates, such as for seasonally-dependent work.

Budget: For each task, provide the total cost to complete the task. Tasks performed by MnDOT personnel may have zero-dollar budgets for the purpose of this work plan.

"Task 1: Finalize Work Plan (3 Months)
Prior to any field inspections, Contractor will:
1.1 Review current Federal Aviation (FAA) rules, technical literature, owners and industry experiences, and ongoing UAS research.
1.2 Develop bridge inspection list based on Phase II research regarding best practices.
1.2 Develop a field work plan for the bridge inspection list. If approvals for these bridges cannot be obtained suitable alternatives will be chosen. This field work plan will address safety concerns and FAA and other agency requirements. Any traffic control required will be coordinated with and provided by State.
1.3 Establish a work schedule and deliverable submission schedule.
1.4 Establish methods of access and schedule equipment.
1.5 Manage the UAS sub-consultant.

Task 2: Field Work and Evaluation (15 months)
Under this task, Contractor will:

2.1 Perform field work at the selected bridges to collect imagery and evaluate the technology to accomplish the project goals.

2.2 Inspect known deficiencies identified during previous inspections with the use of the UAS to evaluate the ability to identify deficiencies using photos and video.

2.3 Enter bridge inspection data in Minnesota's Structure Information Management System (SIMS) providing element condition ratings, photos, videos, etc. based on UAS imagery and information. Inspection by UAS may be entered as a routine inspection of all elements or as an update inspection per the Bridge Owner's request. A routine inspection by UAS will meet the bridge's National Bridge Inspection Standard frequency requirement; therefore, an additional inspection will not be needed by the Bridge Owner.

Task 3: Documentation/Final Study Report (6 Months)
Under this task, Contractor will prepare a final UAS Bridge Inspection Study report, outlining the results from the field work. The report will include the following:

- Executive Summary
- Introduction and Approach
- Review of Current UAS Technology
- Field Work Parameter and Methods
- Field Work Results
- Cost comparison of bridge safety inspection efforts and data collection
- Future Funding Options
- Hyperlinked and electronic copies of inspection video and still photos
- Advantages and challenges identified during field work
- Conclusions and Recommendations

Also included in this task will be the revision of the best practices and safety guidelines developed in Phase II that could be added to the MnDOT Bridge and Structure Inspection Program Manual. The document will be added as a separate chapter or added to the current chapter titled MnDOT Inspection Vehicle Policy Manual.

SCHEDULE SUMMARY: List each task, start and end dates, or attach a Gantt chart.
24 months

DETAILED BUDGET FOR ENTIRE PROJECT

DOLLAR AMOUNT (OMIT CENTS)				
	FY 2017	**FY 2018**	**FY 2019**	**TOTALS**
DIRECT COSTS				
CONSULTANT, CONTRACTOR AND TESTING COSTS (list each contract and its expected cost) Collins Engineering	**$50,000**	**$50,000**		**$100,000**
EQUIPMENT (itemize by vendor) none	**$0**	**$0**		**$0**
SUPPLIES				
TOTAL PROJECT COSTS				**$100,000**

BUDGET BY SUMMARY TASK AND CONSULTANT/VENDOR:

(List task number and dollar value for each task in the work plan. If the project includes consultant contract or vendor P.O., provide breakdown of task budget. Insert additional rows as necessary.)

Task Number	Task Description	Consultant, Vendor or Contractor Name	Cost
1	Finalize Work Plan, plan field work, obtain approvals (3 months)	Collins	$15,000
2	Field Work and Evaluation (15 months)	Collins	$65,000
3	Documentation/Final Study Report (6 months)	Collins	$20,000
			$
		TOTAL PROJECT COSTS	$100,000

COMMENTS/JUSTIFICATION