RETURN BIDS TO:
RETOURNER LES SOUMISSIONS À:
Bid Receiving - PWGSC / Réception des soumissions - TPSGC
1550 D'Estimauville Avenue
1550, Avenue d'Estimauville
Québec
Québec
G1J 0C7

Title - Sujet Mise à jour de la tourelle PIRATES	
Solicitation No. - N° de l'invitation W7701-186676/A	**Amendment No. - N° modif.** 001
Client Reference No. - N° de référence du client W7701-186676	**Date** 2018-01-09
GETS Reference No. - N° de référence de SEAG PW-$BAL-001-17299	
File No. - N° de dossier BAP-7-40215 (001)	**CCC No./N° CCC - FMS No./N° VME**
Solicitation Closes - L'invitation prend fin **at - à** 02:00 PM **on - le** 2018-02-06	**Time Zone** **Fuseau horaire** Heure Normale du l'Est HNE
F.O.B. - F.A.B. **Plant-Usine:** ☐ **Destination:** ☑ **Other-Autre:** ☐	
Address Enquiries to: - Adresser toutes questions à: Tremblay, Marial	**Buyer Id - Id de l'acheteur** bal001
Telephone No. - N° de téléphone (418) 677-4000 (4159)	**FAX No. - N° de FAX** ( ) -
Destination - of Goods, Services, and Construction: **Destination - des biens, services et construction:** Defence R & D Canada - Valcartier / R et D Défense Canada - Valcartier 2459 route de la Bravoure Québec (Québec) G3J 1X5	

SOLICITATION AMENDMENT
MODIFICATION DE L'INVITATION

The referenced document is hereby revised; unless otherwise indicated, all other terms and conditions of the Solicitation remain the same.

Ce document est par la présente révisé; sauf indication contraire, les modalités de l'invitation demeurent les mêmes.

Comments - Commentaires

Vendor/Firm Name and Address
Raison sociale et adresse du fournisseur/de l'entrepreneur

Instructions: See Herein

Instructions: Voir aux présentes

Delivery Required - Livraison exigée	**Delivery Offered - Livraison proposée**
Vendor/Firm Name and Address **Raison sociale et adresse du fournisseur/de l'entrepreneur** **Telephone No. - N° de téléphone** **Facsimile No. - N° de télécopieur**	
Name and title of person authorized to sign on behalf of Vendor/Firm (type or print) **Nom et titre de la personne autorisée à signer au nom du fournisseur/ de l'entrepreneur (taper ou écrire en caractères d'imprimerie)** **Signature**	**Date**

Issuing Office - Bureau de distribution
TPSGC/PWGSC
BFC Bagotville, CP 380
CFB Bagotville, PO Box 380
Bâtiment 62, local 112
Building 62, Room 112
Alouette
Québec
G0V1A0

Ci-joint, les 2 documents mentionnés à la section **A.4 Documents applicables et références** de l'annexe A :

- DA1 : Rapport « PIRATES Current Status » publié en février 2017

- DA2 : Documents techniques et manuels associés aux différentes composantes de la tourelle.

Prendre note qu'ils sont en anglais seulement.

PIRATES Tracker Modernization Feasibility Study – Current status

Abstract

Defense Research and Development Canada (DRDC) Valcartier Research Center uses a Lightweight Optical Tracking System (LOTS) in its research and development program. The tracking system is mounted with hyperspectral measuring instruments to capture the infrared signature of moving targets such as airplanes and flares. It was purchased in 1982 and updated in 2002.

This report, the first of two, provides the current status of the LOTS. A general description of the LOTS is made, followed by a more detailed description of its major components. The communication protocols used between the different components are also described. The report ends with a brief summary on the condition of the different components and on some general recommendations for their replacement if needed.

Résumé

Le Centre de Recherche de Valcartier de Recherche et Développement pour la Défense Canada (RDDC) possède un système de poursuite optique LOTS (Lightweight Optical Tracking System) pour ses programmes de recherche et de développement. Ce système de poursuite peut être équipé d'instruments de mesure hyperspectrale pour capter les signatures infrarouges de cibles en mouvement comme des avions et des leurres. Il a été acheté en 1982 et modifié e 2002.

Dans ce rapport, le premier d'une série de deux, l'auteur fourni une évaluation de la condition actuelle du LOTS. Une description générale du système est effectuée, suivie d'une description plus détaillée de ses composantes majeures. Les protocoles de communication utilisés entre les composantes pour envoyer les différentes informations sont aussi décrits. Le rapport se termine par un court résumé de l'état général des différentes composantes du système et de quelques recommandations si l'on devait les remplacer.

Table of contents

PIRATES Tracker Modernization Feasibility Study – Current status i
Abstract iii
Résumé iv
Table of contents v
List of figures vii
List of tables viii
1 Introduction 9
2 Description of the tracking system 10
2.1 General description and functioning of the LOTS 10
2.2 Description of the components of the LOTS 14
2.2.1 Power unit assembly 14
2.2.2 Azimuth and Elevation motors 14
2.2.3 Encoder 15
2.2.4 Camera 15
2.2.5 Optical acquisition aid (OAA) 15
2.2.6 Joystick 16
2.2.7 Remote Control Unit (RCU) 16
2.2.7.1 A to D I/O interface 17
2.2.7.2 Video overlay card 17
2.2.7.3 Video tracker card 17
2.2.7.4 IRIG-B timing card 17
2.2.7.5 Ethernet interface card 17
2.2.7.6 Acquisition Aid card 17
2.2.8 Pedestal Controller Interface Assembly (PCIA) 17
2.2.8.1 Embedded Controller (EC) 18
2.2.8.2 Embedded Controller Interface (ECI) 19
2.2.9 Servo Amplifier Unit (SAU) 19
2.3 User interface and control software 19
2.3.1 Command mode options 19
2.3.1.1 Standby 19
2.3.1.2 Position 20
2.3.1.3 Track 20
2.3.1.4 Scan 20
2.3.1.5 Acquisition aid submode 20
2.3.2 Manual value changes 20
3 Condition of the components and general recommandation 21
4 Conclusion 24

References/Bibliography.... 25
List of symbols/abbreviations/acronyms/initialismsError! Unknown document property name. 26

List of figures

Figure 1: Photograph of the LOTS. 10
Figure 2: Schematic view of the LOTS. 12
Figure 3: Communication protocols between the components of the LOTS................................ 14
Figure 4: Photograph of the Optical Acquisition Aid without its optical device.......................... 16

List of tables

Table 1: General specifications of the tracker 12
Table 2: Condition of each component and general recommendation on what to do with it........ 21

1 Introduction

Defense Research and Development Canada (DRDC) Valcartier Research Center owns a Lightweight Optical Tracking System (LOTS) or ‘‘tracker’’ on which it is possible to mount hyperspectral measuring instruments that can capture the infrared signature of moving targets such as airplanes and flares. The tracker, bought in 1982 and upgraded in 2002, can be controlled using several devices, namely a joystick, an optical acquisition aid and through an automatic video tracking algorithms. However, some of the different parts and technologies used in the controlling process are getting dated, and some of them might not be replaceable if a problem was to occur.

The main scope of this report is to present the general functioning of the LOTS and a detailed description of its several components in order to fully understand their role in the system. A brief summary of the conditions of these components is also included. Following this work, a second report will provide modernization recommendations and estimates of the cost and time required to perform the suggested modifications.

2 Description of the tracking system

This section provides information about the LOTS and its components. First, an overview of the general functioning of the tracking system and its performance is presented. It is then followed by a specific description of the roles and condition of all its major parts. The communication protocols between the components are also presented. Finally, the software controlling the tracker is presented.

2.1 General description and functioning of the LOTS

The LOTS consists of a tracking system (‘‘tracker’’ or ‘‘pedestal’’) mounted on a trailer. A photograph of the LOTS is presented in Figure 1 and its schematic representation, taken from [2], is presented in figure 2. The whole system weighs around 6000 pounds. It is transportable by truck, train, boat, helicopter or cargo plane. On the tracker mechanical structure, a wide variety of instruments (video cameras, visual optics, thermal imagers, laser range finders and hyperspectral instruments) can be mounted and it has a support payload capacity of 1200 pounds.

Figure 1: Photograph of the LOTS.

The tracker can point at a specific target or aim at moving targets through a wide range of azimuth (AZ) and elevation (EL) angles. The AZ axis performs rotations on the trailer base, while the EL axis performs up and down rotations of the payload. The trailer base of the pedestal is made of a number of brackets, clamps, support beams and other mechanical structures that support the wrapping and unwrapping of the wiring and allowing it to perform its AZ rotation. All the movements of the tracker are generated by 3 DC direct drive torque motors. One is located at its base controlling the AZ axis, and two are located in each arm controlling the EL axis. Each axis is equipped with a digital encoder to measure its position. Several prelimit and limit switches are used throughout the system to stop the movements if needed. The general specifications of the tracker are presented in Table 1, which is taken from [1].

The position control system of the AZ and EL motors is a closed loop servo system. The system is controlled and monitored by dedicated circuit cards and firmware in the Pedestal Controller Interface Assembly (PCIA), which is located on the tracker. The PCIA reads the position of each encoder, then sends it to the Remote Control Unit (RCU), which is located in an office shelter. The RCU consists of a computer and a user interface and control software to select the desired AZ and EL angles and other tracking parameters depending on the selected mode. Once the information is processed, the generated command is sent back to the PCIA that converts it into an analog signal by the Embedded Controller Interface (ECI) cards (1 for each axis) located inside the PCIA. This analog signal is then fed to the Servo Amplifier Unit (SAU), consisting of two drives, which boosts and converts the signal to the actual motor power levels needed to activate the motors.

The system can operate under 2 different modes, automatic or manual, that can be selected from the RCU user interface and control software. In automatic mode, a video signal from a camera located on the tracker payload is fed back to the RCU that processes it and develops tracking commands based on the selected tracking algorithm. In manual mode, the user can use 2 different tools to track moving targets. The first one is a called an optical acquisition aid (OAA), which is basically an orientable optic device mounted on a tripod. The user points at a target with the OAA, and the 2 electromagnetic resolvers mounted on it read its orientation and send it to the RCU so that it can control the tracker in a slave mode. The second tool is a joystick. The operator uses the video feed from the camera mounted on the payload of the tracker and controls the tracker using the joystick.

Technically, it should be possible to switch between all the 3 methods presented above depending on the situation by choosing the appropriate option on the RCU software. However, the joystick and the OAA can’t be used at the same time since 2007 because of an unresolved technical problem that prevents each of their circuit card in the RCU to work at the same time.

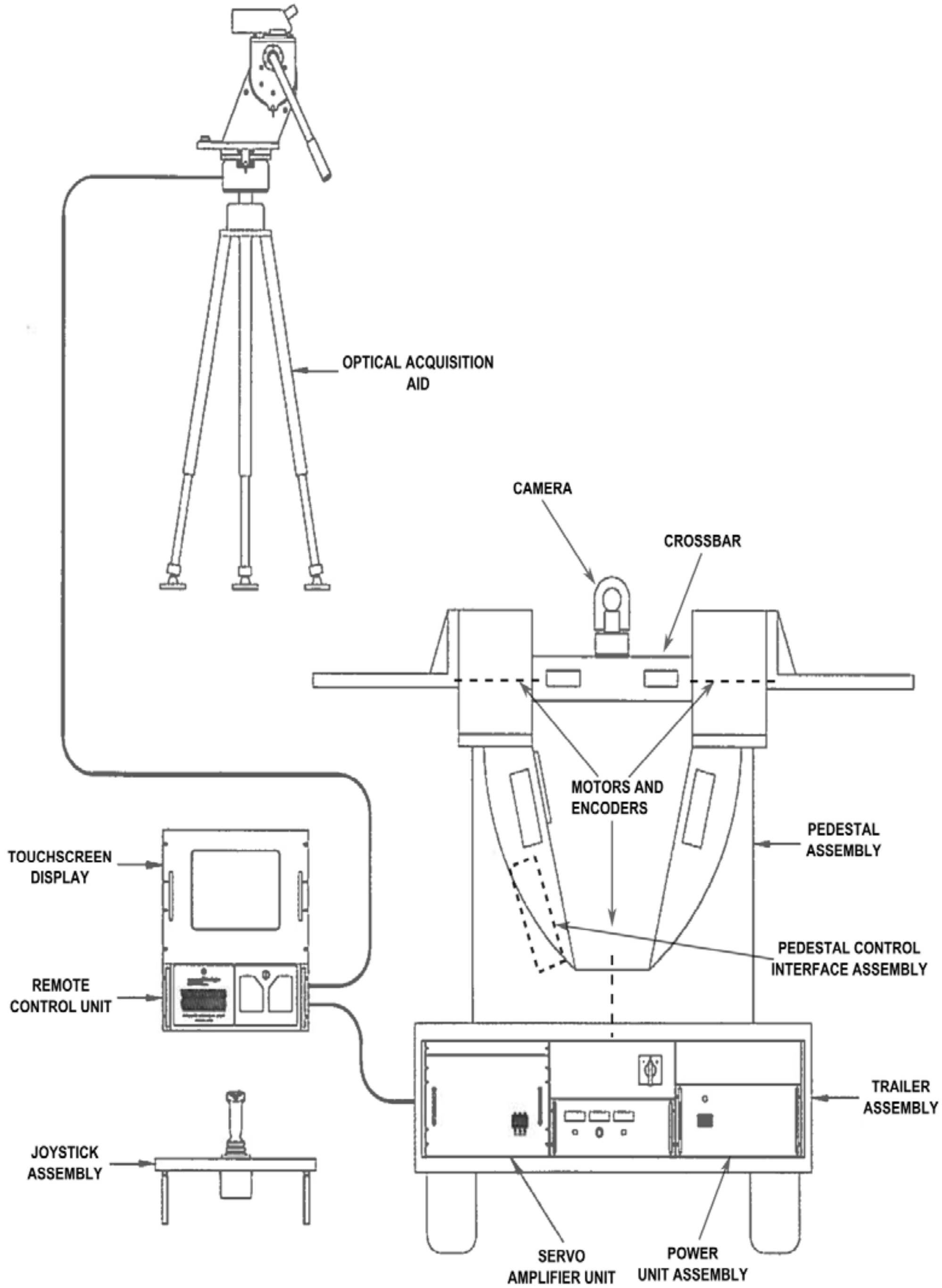

Figure 2: *Schematic view of the LOTS.*

Table 1: *General specifications of the tracker*

Description	Value

Azimuth/Elevation Drive	
Azimuth travel:	
Velocity limits	±230°
Cable wrap warning	±220°
Primary limits	±260°
Dead limits	±265°
Mechanical stops	±273°
Elevation travel:	
Velocity limits	+65° and +25°
Primary limits	-7° and +95°
Dead limits	-10° and +100°
Mechanical stops	-10° and +100°
Angular Velocity	Adjustable to 60°/sec
Angular Acceleration	Adjustable to 60°/sec²
Mechanical	
Axis non-orthogonality	15 arc sec max
Azimuth or elevation bearing runout	±10 arc sec max
Azimuth or elevation bearing wobble	±10 arc sec max
Trailer leveling resolution	30 arc sec or better
Mount leveling resolution	10 arc sec or better
Torque	
Azimuth axis :	
Continuous	400 ft. lbs.
Peak	700 ft. lbs.
Elevation axis :	
Continuous	120 ft. lbs.
Peak	200 ft. lbs.
Power requirement [1]	
Type	208Vac ±5%, 3 phase, 60Hz, ±5%
Power, idle	1 KVA
Power, average	6 KVA
Power, peak	10 KVA
Weight	
Trailer, mount, load mounts and electronics	6000 lbs.
Dimension	
Road clearance	12 in
Length	152 in
Width	84 in
Height	33.5 in
Turning radius	10 ft.
Physical specifications	
Roadability	Unimproved roads to 35 MPH
Transportability	Truck, rail, ships or air
Environment	Weatherproof, shipboard coastal or desert climates

[1] Power required for motors, hardware components and measuring instruments.

2.2 Description of the components of the LOTS

This section presents a more in depth description of all the major components of the LOTS along with their functions in the tracking process and how these components communicate with each other. A schematic of the communication protocols between the components is presented in Figure 3.

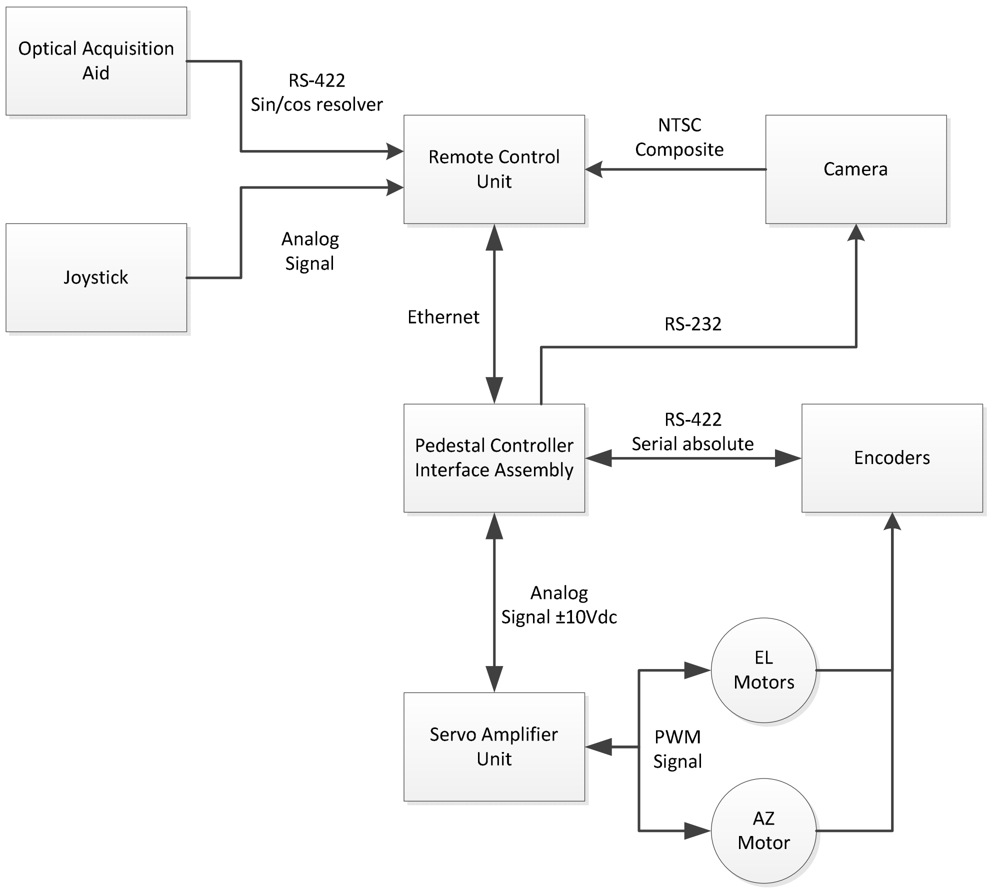

Figure 3: *Communication protocols between the components of the LOTS.*

2.2.1 Power unit assembly

This assembly is located at the bottom of the trailer. The power unit is powered with 3-phased 208 VAC from a fixed or a power generator source. A Bhelman, part number BL10000 C-1-R-L, transforms the incoming AC signal into DC signal then retransforms it into an AC signal with the correct voltage. The Bhelman prevents all the components of the system from being damaged from instability in the current signal that could come from the power generators or the electric network. All the components of the LOTS are powered by this unit, except the OAA and the RCU that are powered by a second power unit located in the office shelter.

2.2.2 Azimuth and Elevation motors

The motors moving the tracker are 3 DC direct drive frameless brush torque motors from the company Inland (now Kollmorgen). The motor located at the bottom of the pedestal activating the AZ axis has the part number QT-23502. Two smaller motors located in each arm of the tracker and activing the EL axis have the part number T-10020-F. The torque capabilities for each axis are listed in Table 1.

2.2.3 Encoder

Each DC motor is equipped with a 16 bits absolute encoder from Gurley Precision Instruments. The product number for the EL encoder is A25S-B16S-012A-06E-0AN and the one for the AZ encoder is A25S-B16S-012A-06E-1AN. The absolute position feature of the encoders is very important, because it allows the system to know its orientation with precision at system startup and removes the need to calibrate it.

All encoders are connected to an absolute serial interface card from Gurley Precision Instruments which interrogates and reads their data when asked by the PCIA. All the information coming from and sent to the PCIA is going through a serial RS-422 cable.

2.2.4 Camera

The camera mounted on the crossbar of the tracker is used for video tracking according to the selected algorithm into the RCU. This camera is a ½ inch 3-CCD sensor from Hitachi, number HV-C20 and has a pixel resolution of 768x494. It is connected to the PCIA by a RS-232 protocol to receive setting modification commands and sends its video data directly to the RCU through a NTSC composite cable. The joystick operator uses the video feed displayed on the screen of the RCU to manually control the tracker.

2.2.5 Optical acquisition aid (OAA)

The Optical Acquisition Aid (OAA) consists of an orientable optic device mounted on a tripod. A photograph of the OAA is presented in Figure 4. The orientation of the optic device is measured by two electromagnetic resolvers from Pacific Scientific Artus, number 26T08RX4AS3D121. The sine and cosine data from the resolvers are sent to the RCU through a RS-422 cable.

The Optical Acquisition Aid (OAA) can be used by an operator for quick acquisition of a target when he points the OAA's optics at a desired target. This occurs when the operator presses the enable button of the handle of the OAA and the RCU software is in position or track mode. The tracker then becomes slave to the target.

In order to reduce the parallax error between the OAA and the tracker to a minimum, the OAA must first be bore sighted to the tracker position angle through a procedure achieved with the RCU software.

Figure 4: *Photograph of the Optical Acquisition Aid without its optical device.*

2.2.6 Joystick

The joystick used to manually control the tracker is made by the company Penny & Giles (now Curtiss-Wright) and its part number is JC6000-XY-RR-L-A30B-STN-N. It is located in the office shelter housing the operator and the RCU and communicates with the RCU through its interface card. The joystick manual mode is usually used in pair along with the automatic video tracking algorithms. For instance, the manual mode can be activated while the automatic mode is running to allow fine-tuning of the placement of the target on the screen for instrument data acquisition purposes. The joystick has 4 buttons, and each of them has a special function.

- Standby: the tracker enters into a wait mode.
- Position: the tracker goes to a predetermined position.
- Tracking: enables the switch between the manual tracking by the joystick and the automatic tracking by the RCU.
- Fast-forward: increases the gain in the joystick so that it orients faster of the tracker. The gains can manually be changed from the RCU software.

2.2.7 Remote Control Unit (RCU)

The Remote Control Unit consists in a ruggedized industrial computer from Kontron and is located in the office shelter housing the operator. The computer contains a custom user interface and control software program from Multitech Corp running on a Red Hat Linux kernel, release 7.3 (Valhalla) 2.4.18-3 custom on an i686. This software receives all the information from the different components of the system and then sends back motor commands to the PCIA. The software provides many functions with the tracker, which can be selected with a touchscreen interface VGA display. A more detailed description of the software is presented in section 2.3. The system also monitors the status of many components within the system to provide fault detection, fault protection and fault warnings for many conditions. Custom circuit cards are installed in the computer to allow communication with the rest of the system. The following circuit cards information is taken from [2].

2.2.7.1 A to D I/O interface

This card is an analog to digital interface is used to receive and transform the data from the joystick. This circuit card is a commercial assembly from Kontron, type AD12-8 and uses a standard ISA bus card that plugs into the motherboard.

2.2.7.2 Video overlay card

This card processes video data from an external or local video source from the tracker (camera) and is used by the RCU to display the data on the screen. This card is a commercial assembly from Hauppauge, type WINTV-PVR250, and uses a standard AGP bus card that plugs into the motherboard.

2.2.7.3 Video tracker card

This card is a digital image processor with a large number of tracking algorithms built into it. These algorithms are presented in section 2.3. This assembly is from Octep Corp., Model ADEPT-34, and uses a standard PCI bus card that plugs into the motherboard.

2.2.7.4 IRIG-B timing card

This card processes timing signals and provides standard reference time stamps for the tracking system. This card is a commercial assembly from Masterlock type TCR-500-PCI and uses a standard PCI bus card that plugs into the motherboard.

2.2.7.5 Ethernet interface card

This card is a dual port high speed Ethernet interface that enables the communication with the PCIA through a standard high speed TCP/IP protocol. Data from the encoders for the AZ and EL axis are sent through this connection to the RCU. The RCU then sends a 12 bits digital command signal to the PCIA to control the servo amplifiers. The PCIA also sends safety data such as motor over-currents, over-speed, temperatures, and other information needed to operate safely. This card is a commercial assembly from Intel, number A67265.

2.2.7.6 Acquisition Aid card

This card is a dual port resolver to digital interface with a digital I/O port. It is connected to the Optical Acquisition Aid through a cable and supplies the excitation to the resolver mounted inside the OAA. The signal is read back as the sine and cosine of that reference, then the angle is digitized and passed to the processor over the ISA bus.

2.2.8 Pedestal Controller Interface Assembly (PCIA)

The Pedestal Controller Interface Assembly is located at the base of the pedestal and is used to monitor and collect the data from the encoders and to control the rate and the position loops for the AZ and EL axis. It also receives the information from all the limit switches on the system. This assembly contains two sets of two circuit card assemblies, and each set is responsible for its own axis. The first circuit card assembly is in charge of the control loops and the second one is in charge of the monitoring of the motors.

2.2.8.1 Embedded Controller (EC)

Each Embedded Controller (EC) card contained within the PCIA controls one axis of the tracker. Each of them is responsible of the data collection and the control of the rate and the position loops for its axis. The EC is the central focus of the PCIA and its major functions include:

- Flash EPROM function
- SDRAM function
- Ethernet function
- PC on a Chip function
- ISA bus
- PC on a Chip bootstrap option
- Master reset function
- Power (2.5V)
- Power (3.5V)
- Power (5V)
- Serial port A function
- Serial port B function
- JTAG port function.

The EC is built around a ‘‘PC on a chip’’ integrated circuit that has the same functions as a personal computer and that actually operates the entire PCIA system. In this case, the flash memory of the EC is loaded with an operating system consisting of a Linux Red hat kernel and a custom software from Multitech. Furthermore, the flash memory allows the EC to retain the operating system when the power is removed from the system. If needed, any updates or changes can be uploaded in the EC through a JTAG programming port. The PC on a chip contains the following functions:

- Processor core
- DRAM controller
- PCI host bridge
- ISA bus
- IDE controller
- USB bus
- Integrated super I/O support
- Fail safe boot ROM
- JTAG interface
- Timers
- Power management
- Software with: Phoenix BIOS, Linux Red Hat Kernel, Multitech software and interface software.

The EC receives the desired information from the Embedded Controller Interface (ECI) over its standard ISA bus. The EC firsts sends a command, then the ECI sends back the data of the actual AZ and EL motor currents, motor temperatures, limit switches states and encoder positions.

The EC is connected to a Local Area Network (LAN) using a standard TCP/IP interface and transmits the tracker position to the RCU through it.

2.2.8.2 Embedded Controller Interface (ECI)

The Embedded Controller Interface (ECI) cards are responsible for the data collection of the motors and the encoders. They also send the analog torque commands to the SAU. Furthermore, they feed the tracker position data to two LED display screens located on the crossbar of the tracker. There is one ECI card for each axis. The major functions of the ECI include:

- AD converters – Azimuth or Elevation
- AD converters – Temperature sensor
- ISA logic
- Power supply - +15VDC
- Power supply - +5VDC
- Power supply - -15VDC
- Resolver interface -all
- Encoder interface – Reference clock
- Temperature sensor interface

The ECI transforms its data through its A/D and D/A converters and sends it to the EC through an ISA bus when it is asked to do so.

2.2.9 Servo Amplifier Unit (SAU)

The Servo Amplifier Unit is located in the rear bay enclosure of the trailer and contains the power servo amplifiers of the system that drive the AZ and EL motors to the desired levels. The AZ and EL control analog torque signals are received from the PCIA. The two amplifiers used in this system are 12-Bits Copley Controls Xenus #XTL-230-40-R-HL servo drives. These amplifiers have a flash memory, which allows them to retain their data when the power is removed from the system. When it receives the analog signals, the drive transforms it through its A/D converter, then generates a PWM signal to the motors according to the level required.

This assembly has also a system safety and protective function. Safety relays in the SAU can de-energize and remove the AC power from the amplifiers, which removes all power from the torque motors. This system is designed to fail safe.

2.3 User interface and control software

This section presents a brief description of the software located into the RCU and developed by Multitech Corp. This software is the main interface between the operator and the tracker. It can perform multiple functions such as commanding the tracker to aim at specified positions or targets, managing the faults and the warnings of the system, modifying the control behavior of the tracker and many more.

2.3.1 Command mode options

2.3.1.1 Standby

This is the default mode after system startup and reboot. In this mode, the servo amplifiers and the motors are disabled.

2.3.1.2 Position

In position mode, the operator controls the pedestal assembly position from the front panel by selecting a desired angle in degrees. The software can also remember 5 preset positions chosen by the operator.

2.3.1.3 Track

The track mode allows automatic tracking based on signals from the video tracker card. The tracking can be done according to different algorithms.

Correlation. This algorithm takes the XY coordinates of the target pixels and performs a numerical average. The system takes the mean value of the X coordinates of all target pixels as the X coordinate and the mean value of the Y coordinates as the Y coordinate of the target

Centroid. This algorithm does a mean average of the target pixels and assigns a weighted average relative to the value of the pixel. The hotter pixels have a stronger weighted value than the colder pixels.

Multiple Target Track (MTT). This algorithm is used for tracking objects that are fully contained within the track window. The MTT gives good performance with small targets in high clutter.

Edge track. This algorithm uses the X and Y coordinates of the video edge selected as coordinate of the track. The operator can manually or automatically add an offset to the tracking if needed.

2.3.1.4 Scan

In Scan mode, the operator can manually pre-program scan trajectories for the tracker based on different types of patterns like direct line, circle or spiral.

2.3.1.5 Acquisition aid submode

This submode allows the system to be slaved to the acquisition aid by pressing the enable button on the OAA handle when the system is in position or track mode. The calibration of the OAA to minimize the parallax error must be done in the software before operating in this submode.

2.3.2 Manual value changes

The software offers the possibility to manually change a great amount of numerical values that represent physical information of the tracker in the system. For example, the operator can adjust the maximum velocity and acceleration of the tracker, add softlimits to the maximum angular displacement of the tracker or adjust the estimated inertia of the payload to improve the control of the tracker.

3 Condition of the components and general recommandation

This section presents the condition and the reported problems of all the components described in section 2 along with a general recommendation to change or keep the component. The information is presented in Table 2

Table 2: *Condition of each component and general recommendation on what to do with it.*

Component	Condition and reported problems	Recommendation/ Requirement
Pedestal and trailer	The mechanical structure of the pedestal is working properly and has no reported issue.	Keep
Power unit	This assembly is working properly.	Keep
Motors	The motors are working properly.	Keep
Encoders	The encoders are working properly.	Keep. If they had to be replaced for some technical reason, the new encoders should be absolute.
Camera	The camera is working properly. However, it would be appreciated by the client to have a better resolution and to replace the NTSC composite cable by an Ethernet cable.	Replace the camera by an Ethernet camera (GigE Vision interface standard) with better resolution.
Optical Acquisition Aid (OAA)	This assembly is working properly.	Keep. If needed, the resolvers of the OAA could be replaced to fit with the new system components.
Joystick	The joystick is working properly.	Keep. If needed, this component could be replaced to meet the communication protocols specified by the new system.
Pedestal Controller Interface Assembly (PCIA)	The cards in this assembly are custom made and could not be replaced if they were to break.	Replace this assembly by a commercial controller interface. The two LED screen display showing the angle data on the tracker crossbar should be kept.
Remote Control Unit (RCU) and software	This Unit is aging and could be more powerful. The two circuit cards doing the joystick/RCU and the OAA/RCU interface can’t work at the same time preventing the users from being able to do full manual	Replace this Unit. The new software should be more user friendly and have at least the same functions as the actual software. A data log of the experiments

	tracking. The software is reported not being really user friendly. The software doesn’t readily allow the user to get a log of the tracking for further analysis. The software allows to manually change a lot of different parameters, however it is not clear what they all represent and how a change in a value affects the system. The calibration with the OAA is only accurate for a limited range of AZ angles (the parallax error increases fast).	should be easy to export from the new software. The calibration protocol with the OAA should add more parameters to adjust by the user to reduce the parallax error at AZ angles far from the initial bore-sighted angle. The OAA and the joystick have to be able to work at the same time.
Servo Amplifier Unit (SAU)	It has been reported that the previous drives (14 bits) installed in the SAU could perform better tracking performances than the actual ones (12 bits).	Replace the SAU. The drives should have at least 14 bits and a flash memory to contain the control program. If possible, they should resist to a temperature of -20°C

4 Conclusion

This report presented a general description of a Lightweight Optical Tracking System used by DRDC Valcartier Research Center to capture the infrared signature of moving targets such as airplanes and flares. A more detailed description of the LOTS components and their communication protocols was also presented.

The main scope of this report was to evaluate the current status of the tracking system in order to evaluate its functioning and to give a general idea on what components should be replaced to modernize it. Based on this evaluation, a second report will provide specific modernization recommendations and estimates of the cost and time required to perform the suggested modifications.

References/Bibliography

[1] Operation and maintenance manual for lightweight optical tracking system (LOTS) Canadian defense, ABA Electromechanical Systems, Inc., Pinella Park, Florida, 1983.

[2] Operation Manual M286SYS001, Modifications to the Lightweight Optical Tracking System LOTS, EMS Technologies, Norcross GA, 2003, pp. 37-38.

List of symbols/abbreviations/acronyms/initialisms Error! Unknown document property name.

AC	Alternative Current
AZ	Azimuth
DC	Direct Current
DRDC	Defence Research and Development Canada
EC	Embedded Controller
ECI	Embedded Controller Interface
EL	Elevation
LOTS	Lightweight Optical Tracking System
MTT	Multiple Target Track
OAA	Optical Acquisition Aid
PC	Personal Computer
PCIA	Pedestal Controller Interface Assembly
PWM	Pulse Width Modulation
RCU	Remote Control Unit
RDDC	Recherche et Développement pour la Défense Canada
SAU	Servo Amplifier Unit

PIRATES Tracker Modernization Feasibility Study

Modernization plan

Table of contents

Table of contents 1
1. Tracker specifications and expected modifications..2
1.1 Current status of the LOTS 2
1.2 LOTS modernization specifications...4
1.2.1 Tracker (pedestal)..4
1.2.2 Tracking system..5
1.2.3 User Interface and Control Software (UICS) 6
2 Hardware cost modification estimates..8
2.1 Component replacement solutions 8
2.1.1 Pedestal Controller Interface Assembly 8
2.1.2 Servo Amplifier unit...9
2.1.3 Encoder...10
2.1.4 Camera and lens 10
2.1.5 Optical Acquisition Aid (OAA) 12
2.1.6 Joystick..12
2.1.7 Remote Control Unit 13
2.2 Modification cost and time global estimate...14
References/Bibliography.... 17

1. Tracker specifications and expected modifications

This sections presents the current status of the LOTS along with the suggested recommendations made for every reported problems. It is then followed by a presentation of the expected work to modernize the LOTS. Finally, based on its required performances, the specifications of a modernized LOTS are presented

1.1 Current status of the LOTS

Table 1 presents the current status and the reported problems of every component of the LOTS along with recommendations on if the components should be kept or replaced. This Table is taken from [1].

Table 1:*Condition of each component and general recommendation on what to do with it.*

Component	**Condition and reported problems**	**Recommendation/ Requirement**
Pedestal and trailer	The mechanical structure of the pedestal is working properly and has no reported issue.	Keep
Power unit	This assembly is working properly.	Keep
Motors	The motors are working properly.	Keep
Camera	The camera is working properly. However, it would be appreciated by the client to have a better resolution and to replace the NTSC composite cable by an Ethernet cable.	Replace the camera by an Ethernet camera (GigE Vision interface standard) with better resolution.
Optical Acquisition Aid (OAA)	The two circuit cards doing the joystick/RCU and the OAA/RCU interface can't work at the same time preventing the users from being able to do full manual tracking.	Replace the interface card in the SAU.
Joystick	The two circuit cards doing the joystick/RCU and the OAA/RCU interface can't work at the same time preventing the users from being able to do full manual tracking.	Replace the joystick and the interface card in the SAU.
Pedestal Controller Interface Assembly	The cards in this assembly are custom made and could not be replaced if they were to break.	Replace this assembly by a commercial motion controller. The new assembly must perform the same function as the actual one.

(PCIA)		
Encoders	The encoders are working properly. However, they use an unusual communication protocol that would not be compatible with any new motion controller.	Replace for new absolute encoders compatible with the selected motion controller.
Remote Control Unit (RCU) and software	This Unit is aging and could be more powerful. The software is reported not being really user friendly. The software doesn't readily allow the user to get a log of the tracking for further analysis. The software allows to manually change a lot of different parameters, however it is not clear what they all represent and how a change in a value affects the system. The calibration with the OAA is only accurate for a limited range of AZ angles (the parallax error increases fast).	Replace this unit for a state of the art technologie with good computing power. The new software should be more user friendly and have at least the same functions as the actual software. A data log of the experiments should be easy to export from the new software. The calibration protocol with the OAA should add more parameters to adjust by the user to reduce the parallax error at AZ angles far from the initial bore-sighted angle.
Servo Amplifier Unit (SAU)	It has been reported that the previous drives (14 bits) installed in the SAU could perform better tracking performances than the actual ones (12 bits).	Replace the SAU. The drives should have at least 14 bits and a flash memory to contain the control program.

An analysis of Table 1 allows to make some conclusions about the modernization work that has to be achieved on the LOTS. While the motors and mechanical structure are working properly, the majority of the other hardware components have to be replaced, which include: the motion controller, the drives, the encoders, the camera, the joystick, the computer and the interface cards. A replacement solution for those components is presented in Section 2. Integrating all components together and replacing the computer implies that a new software has to be developed, since DRDC doesn't own the source code of the current software. An estimate of the time required to develop a software with special functions such as automatic target tracking is presented in Section **Error! Reference source not found.**.

1.2 LOTS modernization specifications

This section presents the specification that the LOTS must achieve by the end of its modernization. The specification is divided in three different categories: the pedestal, the tracking system and the user interface and control software. For system description see ref [1].

1.2.1 Tracker (pedestal)

a. The tracker pedestal must operate within the following original tracker specification values with a load of 1200 lbs.:

Table 2:*Mechanical specifications of the pedestal.*

Description	Value
Azimuth/Elevation (AZ/EL) Drive	
Azimuth travel:	
Velocity limits	±230°
Cable wrap warning	±220°
Primary limits	±260°
Dead limits	±265°
Mechanical stops	±273°
Elevation travel:	
Velocity limits	+65° and +25°
Primary limits	-7° and +95°
Dead limits	-10° and +100°
Mechanical stops	-10° and +100°
Angular Velocity	Adjustable to 60°/sec
Angular Acceleration	Adjustable to 60°/sec²
Mechanical	
Axis non-orthogonality	15 arc sec max
Azimuth or elevation bearing runout	±10 arc sec max
Azimuth or elevation bearing wobble	±10 arc sec max
Trailer leveling resolution	30 arc sec or better
Mount leveling resolution	10 arc sec or better
Torque	
Azimuth axis:	
Continuous	400 ft. lbs.
Peak	700 ft. lbs.
Elevation axis:	
Continuous	120 ft. lbs.
Peak	200 ft. lbs.
Power requirement (for motors, hardware components and measuring instruments)	

Type	
Power, idle	208Vac ±5%, 3 phase, 60Hz, ±5%
Power, average	1 KVA
Power, peak	6 KVA
	10 KVA

b. Each hardware components of the system must be commercial of the shelf.
c. Each component containing any type of software/firmware must have it loaded into a flash memory.
d. The tracker must operate from temperature of 0°C to 40°C
e. The tracker should operate from temperature of -20°C to 40 °C.
f. The new components should use the cables and wires already in place within the tracker.
g. The system must use absolute encoders.
h. The servo amplifier system powering the motors must have a resolution of at least 14 bits.
i. The servo amplifier system must be contained into a 19'' rack enclosure.
j. The controllers must be connected to the computer using Ethernet cables.
k. The value of the actual AZ and EL angles must be displayed on the crossbar of the tracker.
l. The joystick and the Optical Acquisition Aid (OAA) must communicate through the computer port using interface cards.
m. The joystick and the OAA should communicate directly through a USB computer port using no additional interface cards or external hardware.
n. The joystick must have at least 4 buttons that can perform different functions when pressed (Standby, Position, Tracking, Fast-Forward) as described in ref [1].
o. The system must have two cameras that can track and detect moving targets in the infrared spectrum and in the visible spectrum from a distance of 750m to 1500m. If only one camera can be plugged at a time, the system must use presets for quick transfer. Changing from one camera to the other must be really simple.
p. The cameras must use an Ethernet cable with a GigE Vision interface standard.

1.2.2 Tracking system

a. Must be able to automatically track moving targets based on several tracking algorithms.
b. Must be able to manually track moving targets using the Optical Acquisition Aid (OAA) and a joystick.
c. When used, the OAA must be able to put the tracker into a slave mode.
d. The system must allow two operators to operate the joystick and the OAA in the same tracking event and allow them to switch from one mode to the other by pushing a single button.
e. The user must be able to change from a manual tracking mode to an automatic one when needed, and vice versa.
f. When bore sighted, the OAA must have a very low parallax error with the payload cameras for a very wide range of AZ angles. The operator must have an adjustment mean to reduce the error.
g. The system must be designed to fail safe.
h. The system must be designed to not exceed a power requirement of 10kVA with its instruments in operation.

1.2.3 User Interface and Control Software (UICS)

a. The UICS must be located on a PC type platform.
b. The system must know its orientation at start-up.
c. The tracking algorithms must be selectable from the main screen.
d. The selection of tracking algorithm must be modifiable easily from one tracking event to another.
e. A video feed of the tracking camera must be displayed on the user interface screen at any time at 30Hz.
f. The visible and IR camera must be time stamped.
g. The UICS must allow an overlay display of the tracking AZ, EL and date/time on the video image or in the proximity of the image on the screen.
h. The different faults and errors of the system must be displayed on the main screen.
i. The UICS must permit the configuration setting of all tracking system parameters. When applicable, the units of each parameter must be displayed along with a description of its effect on the system.
j. The computer operating system must operate in real time.
k. The data log including all user interface and control parameters, video images, pedestal pointing locations must be recorded during tracking events.
l. The data log must be selectable from the user interface and importable through a USB port.
m. Tracking events must be replayable.

2 Hardware cost modification estimates

This section presents a cost estimate of the required modifications in the hardware components of the system. For each component, at least one replacement solution is proposed along with the component cost and its advantages. The information is then collected into

Table 11 to make it easier to visualize.

2.1 Component replacement solutions

As mentioned above, the majority of the components of the LOTS have to be replaced in order to modernize the tracker, while some other components could be left untouched. The untouched components include the mechanical structure of the tracker, the motors, the power unit and most of the internal wiring. The rest of the system, basically consisting of the control system, has to be replaced. The next subsections propose at least one modification solution for every component. When more solutions are proposed, the best one is presented first.

As the majority of the actual components are custom made or are relying on unknown programs and algorithms, the main idea of the modernization is to propose Commercial Off The Shelf (COTS) components that can easily by replaced in case of a problem. When applicable, the selected components come with an application programming interface (API) and program examples to simplify the integration.

2.1.1 Pedestal Controller Interface Assembly

The current Pedestal Controller Interface Assembly consists of custom made cards which have the function to control the axis of the tracker and manage the communication with several other components.

2.1.1.1 Galil Motion controller

Description

The author proposes to replace the whole assembly by a COTS motion controller from Galil Motion Inc. This motion controller can control 2 axis at the same time, communicates through an Ethernet protocol with a computer, and has the required ports to interact with the other components around it, which are the drives, the encoders, the limit switches, the camera, the motorized lens and the crossbar orientation display. Its general specifications are presented in Table 3. The specifications and much more information about this product can be found on Galil website [2]. The quote and description of the product are presented in **Error! Reference source not found.**.

Table 3: *General specifications of the Galil motion controller.*

Part number	DMC-4020(16BIT)-C012-I200(SSI,24V,HAEN,Source)
Connectors	2-axis Ethernet/RS232

	Single Ethernet Communications Board Separate axis connector external Amps SSI encoders
Options	16bit ADC

Cost of the hardware

Motion Controller:

Male to male connectors:

Suite of Software Tools for Galil Hardware:

2.1.2 Servo Amplifier unit

The current drives in this unit are working properly, however it has been reported that their actual resolution (12 bits) does not optimise the performances of the motors.

2.1.2.1 Copley Control Drive

Description

The author proposes to replace the currents drives by two 16 bits drives from Copley Control. The advantage of using these drives is that they are the same model as the actual ones, so that the installation would be done really fast. The general drives specifications are presented in Table 4. The specifications and much more information about this product can be found on this website [3]. The quote and description of the product are presented in **Error! Reference source not found.**.

Table 4: *General specifications of the Copley Control drive.*

Part number	Copley Control Xenus XTL-230-40
Continuous/Peak current	20/40 A
Command	Analog Torque +- 10Vdc
Resolution	16 bits

Cost of the component

2.1.2.2 Kollmorgen ServoDrive

Description

The second option is a Kollmorgen servo drive. This drive would be an alternative to the Copley Control drive as they perform the same function, except that its installation would require more time. The general specifications of this drive are presented inTable 5. The specifications and much more information about this product can be found on this website [4]. The quote and description of the product are presented in **Error! Reference source not found.**.

Table 5: *General specifications of the Kollmorgen drive.*

Part number	AKD-B02406-NBAN-0000
Continuous/Peak current	24/48 A
Command	Analog Torque +- 10Vdc
Resolution	16 bits

Cost of the component

2.1.3 Encoder

The current encoders work properly, however they use a communication protocol that does not allow to communicate with the new motion controllers.

2.1.3.1 Fraba absolute rotary encoder

Description

The author proposes to replace the current encoders by two absolute rotary encoder from Fraba Inc. They provide the same resolution (16 bits) as the current ones, but communicate with a standard Synchronous Serial Interface (SSI) protocol that would work with the new motion controller. The general specifications are presented in Table 6. All specifications and much more information about this product can be found on this website [5]. The quote and description of the product are presented in **Error! Reference source not found.**.

Table 6: *General specifications of the encoder.*

Part number	UCD-SSE1B-1616-R100-PRP
Singleturn/Multiturn Resolution	Absolute 16 bits / 16 bits, 16384 Pulses per revolution
Communication protocol	Synchronous Serial Interface (SSI)
Connectivity	Flange Design:Synchro, Flange Size: 36 mm, Shaft Diameter: 10 mm, Radial 2m M23 Male 16 pin, Incremental RS422

Cost of the component

Encoder:

Encoder cable:

2.1.4 Camera and lens

Description

Visible camera

The author proposes to use a Prosilica GT2000NIR camera to perform the tracking. This camera has a 2/3" CMOS color sensor with a resolution of 2048x1088. Its frame rate at full resolution is 53.7. This camera has a Near Infrared (NIR) filter which would offer a better detection when the luminosity starts to decrease. Its description is presented in Table 7 and its specification and price can be found on this website [6].

Table 7: *General specifications of the camera.*

Camera Part number	Prosilica GT2000NIR
Sensor	2/3" progressive scan CMOS color sensor
Frame rate	53.7 fps
Sensing area	11.3 x 6
Communication protocol	GigE Vision
Mounting	C-mount

Lens

The author suggest to use a motorized zoom lens with the camera, so that the size of the moving objects on the image would be adequate to perform tracking algorithms. The suggested lens is from Computar, part number M24Z1527PDC-MP. Its general description is shown in Table 8 and its specification can be found on this website [7]. The quote if this product is presented in **Error! Reference source not found.**.

Table 8: *General specifications of the lens.*

Lens part number	M24Z1527PDC-MP
Zoom	Optical zoom 24x
Focal length	15-360 mm
Mounting	C-mount

Mid Wave Infrared (MWIR) camera

We talked with the company FLIR to know which of their product could meet the required specifications in term of infrared tracking. Their suggestion was to use the RS-series cameras, which have Midwave detectors. They provided a price for the RS8300, which has an adjustable zoom lens. They pointed out that some other less expensive cameras from this serie could also meet the requirements, however they would not have an adjustable lens and an enclosure. More detail on this product can be found on this website [8].

Important note

A thumb rule for automatic tracking algorithms is “the more data you have the better”. This means that a good resolution and frame per second (starting from around 30) increases the chances to successfully track objects. The current ethernet cable installed on the tracker is rated Cat5, which offers a bandwidth of 100Mbits/s. This means that at full resolution, the proposed camera could transfer at most 4 frames per second to the computer, which does not allow the possibility to perform any tracking. It could be possible to greatly reduce the camera resolution to increase its frame rate, however this would offer the same performance as the current camera installed on the tracker. ***In order to increase the performances of any video tracking algorithm, it would be recommended to use a more recent Ethernet cable than the one currently installed on the tracker.***

Cost of the component

Visible Camera:

Lens:

MWIR camera :

2.1.5 Optical Acquisition Aid (OAA)

This component is working properly, however it has been reported that its interface card prevents this system from working at the same time as the joystick.

2.1.5.1 Synchro Resolver/Digital Interface Card

Description

To fix this system, the author proposes to replace its interface card located in the remote control unit, because it is the component that is causing problem with the joystick. The rest of the OAA can be left untouched. When discussed with the distributor, he confirmed that the resolvers can still work for many years and that their technology is far from being obsolete. All specifications and much more information about this product can be found on this website [9]. The quote of the product is presented in **Error! Reference source not found.**.

Cost of the component

Interface card:

2.1.6 Joystick

This component is working properly, however it has been reported that its interface card prevents this system from working at the same time as the OAA.

2.1.6.1 Logitech Extreme 3D pro USB joystick

Description

The author proposes to use a USB gaming joystick from Logitech to replace the current one. This multi-axis joystick comes with many buttons that can be mapped to any function when plugged in the computer. This kind of joystick removes the need to use an interface cards, which reduces the integration time and the risk of failure. Furthermore, it has been reported that even if this is not designed for industrial needs, this particular joystick works pretty well in terms of precision and durability. The specifications and information about this product can be found on this website [10].

Cost of the component

2.1.6.2 Penny & Giles multi-axis industrial joystick

Description

A ruggedized alternative is the JC8000 joystick from Penny & Giles. This joystick offers precisions and durability and it comes with many buttons as required in the specification. This device communicates with the computer through a CAN/USB converter. The general designation of this joystick is presented in Table 9 and its specification can be found on this website [12]. The quote of the product is presented in **Error! Reference source not found.**.

Table 9: *General designation of the Curtiss-Wrightjoystick.*

Part number	JC8000-XY-M-PP-S-M-0000-S-HEXX-X-X-N-A with handle HE-GEN-NNNN-NN-NN-IRNN04-TRY-N-NNN-N-STD-NN
CAN/USB converter	HD67390-U-D1

Cost of the component

Joystick :

CAN/USB converter :

2.1.7 Remote Control Unit

Description

The author proposes to replace all the components of this unit by up to date ones. The current computer would be replaced by a new computer that offers better performances. This computer would have the needed ports to communicate with the rest of the system. It would also be designed to hold the interfaces cards required to communicate with the other components. Some of the general specifications of the new computer are presented in Table 10. The quote of the product and its specification is presented in **Error! Reference source not found.**.

Table 10: *General specifications of the computer.*

Dimension	4U chassis
Processor	Intel i7 -6700 Quad Core Processor 3.4 GHz/8MB Cache
Memory	DDR3/DDR4: 8GB DDR4-2133/PC4-17000
Video Card	PCI-Express GeForce GTX 1060 6GB DDR5
Additional Network Ports	Two Intel Gigabit (10/100/1000) PCI-Express (4 total)
Cables –Serial Port	Dual 9 pin Serial ports with Bracket
Operating System	Microsoft Windows 7 Pro 64 bits

To display the video data and the user interface, a new 20” rackmount LCD Monitor with USB Touch screen would be installed. All specifications and much more information about this product can be found on this website [11].The quote of the product is presented in **Error! Reference source not found.**.

Cost of the component

Computer:

Monitor:

2.2 Modification cost and time global estimate

This section presents the global estimate of the hardware modification cost required to modernized the hardware. The results are presented in

Table 11, which adds up all the best solutions presented in Section 2.1. Taxes are not included. Since there is no exact price know for the MWIR camera, the total price estimate doesn’t take it into account.

Table 11: Total modernization cost for the hardware components.

Component	Description	Company	Price (Cad)	Number required	Total price (CAD)
Motion Controller	Motion controller DMC-4020(16BIT)-C012-I200(SSI,24V,HAEN,Source)	Galil Motion Control Inc.			
	Suite of Software Tools for Galil Hardware	Galil Motion Control Inc.			
	Homemade connectors				
Servo Drive	Xenus XTL-230-40 16 bit	Copley Control			
Encoder	Absolute rotary encoder	FRABA Inc.			
	Encoder Cable	FRABA Inc.			
Remote Control Unit	Computer 4U chassis	Industrial Computers Inc.			
	20" rackmount LCD touchscreen monitor	Industrial Computers Inc.			
Joystick	Extreme 3D pro USB joystick	Logitech			
Tracking aid	Interface card SB-36243IA-3L0	Data Device Corporation			
Camera	Prosilica GT2000NIR	Allied Vision			
Lens	Lens M24Z1527PDC-MP	Computar			
				TOTAL	

presents the different tasks and time required to perform the modifications of the components that interact with the motion controller such as the encoders, the drives, the camera and the computer. This table does not include the estimated time required to do the interface between the software and the camera, the Optical Acquisition Aid, the joystick and the motion controller. The interfacing is considered as a software function, which is discussed in Section **Error! Reference source not found.**. The integration of the MWIR camera is not taken into account in this Table.

References/Bibliography

[1] "PIRATES TRACKER CURRENT STATUS", February 2017.

[2] Galil motion control website: http://www.galil.com/motion-controllers/multi-axis/dmc-40x0?gclid=CMCNpu2o79ICFdiKswodFM8IBQ

[3] Copley Control drives : http://www.copleycontrols.com/Motion/Downloads/xenusData.html

[4] Kollmorgen drives : http://www.kollmorgen.com/en-us/products/drives/servo/akd/

[5] Fraba encoders : https://www.posital.com/en/

[6] Allied Vision Camera : https://www.edmundoptics.com/cameras/gigabit-ethernet-cameras/allied-vision-prosilica-gt-series-gige-cameras/88475/

[7] Computar Lens : http://computar.com/resources/files_v2/1641/M24Z1527PDC-MP_03-15.pdf

[8] FLIR MWIR cameras http://www.flir.ca/science/display/?id=46795

[9] Data Device corporation R/D interface card : http://www.ddc-web.com/Products/176/Default.aspx

[10] Logitech Extreme 3D pro USB joystick : http://gaming.logitech.com/en-ca/product/extreme-3d-pro-joystick

[11] Rackmount touchscreen : http://www.eindustrialcomputers.com/ProductCart/pc/Rack-Mount-20-LCD-Monitor-9U-48p435.htm

[12] Curtiss-Wright joystick : http://www.gsglobalresources.com/product/control/penny-giles-jc8000/