High-Speed PTZ Camera for Law Enforcement Vehicle application (January 2019)

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***Abstract*—This paper is the 8th project update report for Spring 2019 ME597 class at Purdue University. In this article, you will be provided with state of the art in the field of mobile PTZ camera, specific for law enforcement applications. This article also includes analysis and improvement for the current system.**

***Index Terms*— Law enforcement, PTZ camera, control.**

I. Introduction

THIS document provides brief background information of current camera that using in the field of law enforcement vehicle. It also introduces the current mobile PTZ camera been tested, including its working principle, communication protocol, some problems were found during the testing, as well as the goal of this project and the basic method to achieve this goal.

This article also includes market identification for this product.

II. State of the Art

In North America, most law enforcement patrol vehicles have fixed in-car cameras mounted inside the windshield. They are usually positioned at a fixed angle and focal distance, facing the front of the vehicles. However, as many examples show, sometimes the vehicles were not driving or parking at a perfect angle to provide the best camera footage. Therefore, the videos from that camera can miss important evidence. This kind of evidence missing may lead to acquitted of a charge of an actual offender.

There is something better in this field. The current product has been working on is the remote control PTZ camera. It usually mounted on top of the vehicle, and able to control by an operator inside. The camera has three degrees of freedom: Horizontal, Vertical, and Zoom, also known as Pan–Tilt–Zoom (PTZ), usually communicate with the controller by RS-485 with PELCO-D protocol or by ethernet inside the vehicle. The system is usually equipped with an infrared unit and speed radar, which allows officers to recon the area without notice by the suspect. The current system is also capable of remote video transfer and remote control.

Fig. 1. The PTZ camera that been tested in this project, the lens is on the left side of the picture and the infrared unit on the right side.

(A short video for the PTZ camera operation can be found here: http://v.douyin.com/Fa8vdG/)

Fig. 2. Carrier vehicle been used in this project.

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A. Current problem

When trying to introduce this kind of camera to US Law Enforcement market, we test the equipment with TCARES (Tippecanoe County Amateur Radio Emergency Service) during Wabash River Ride, which is a bicycle competition crossing several counties in Indiana. During the test, we perform maneuvers to simulate patrol and pursuit environment. Then, the camera been found out have poor high-speed stability. It is extremely hard to control the camera pan–tilt when driving at high way speed (above 65 mph). The camera was tending not to respond to moving orders, or not moving to expected positions.

B. Improving goals

During this semester the author will try to improve the control stability for the current problem stated above. The improving will mainly focus on the Horizontal and Vertical axis since the zooming function works just fine under high-way speed. The goal is to make the camera response to every order the controller send out, without missing. Delay within 0.5 seconds will be accepted at this time. The current example of product available is a PELCO-D protocol camera. Therefore, the author will try to improve control through RS-485 and PELCO-D protocol to achieve the design goals. Later on, an Ethernet-controlled camera may be provided, depends on the market demand.

TABLE I
PELCO-D PROTOCOL

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Sync	Camera Address	Command 1	Command 2	Data 1	Data 2	Checksum

TABLE I-I
Command 1 and 2 details

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Command 1	Sense	Reserved	Reserved	Auto / Manual Scan	Camera On/Off	Iris Close	Iris Open	Focus Near
Command 2	Focus Far	Zoom Wide	Zoom Tele	Tilt Down	Tilt-Up	Pan Left	Pan Right	Fixed to 0

More details regarding PELCO-D protocol please see appendix.

III. The Benefit of the New System

If the high-speed stability of the mobile PTZ camera been improved, it allows the police officers to operate the camera in a much convenience way. Furthermore, with a stable control, developers can easily add more function to the system with Visual Identity, including real-time patrolling video transmission, automatic speed radar, which looks around measure all the vehicle speed around the cruise, and automatic tracking suspect vehicle during a high-speed pursuit.

IV. Market Identification

We aim our costumes as law enforcement departments, which already using in-car cameras or planning to use in-car cameras, to upgrade their vehicle camera system to our high-speed PTZ camera system.
Base on “Combined Ford Police Vehicle Sales Numbers” published by Ford in 2018. Ford sold a total of 41,221 police-vehicle in the year of 2018, and Ford claims 60% of the police vehicle market. The total market size for police vehicle is around 68,700 vehicle per year.
From the same table, the growth rate from 2017 to 2018 is (41220-41069)/41069=0.37%. However, the growth rate from 2014 to 2018 is (41220-30889)/30889=33.44%

TABLE II
COMBINED FORD POLICE VEHICLE SALES NUMBERS

Year	Jan	Mar	May	Jul	Sep	Nov	Total
2018	3,684	3,520	4,034	3,022	2,970	3,249	**41,221**
2017	2,907	3,803	3,823	3,409	2,880	3,206	**41,069**
2016	2,803	3,727	3,743	3,416	3,232	3,231	**41,685**
2015	2,719	3,233	3,556	2,813	2,624	2,251	**34,707**
2014	1,794	2,470	3,251	3,249	2,889	2,112	**30,889**

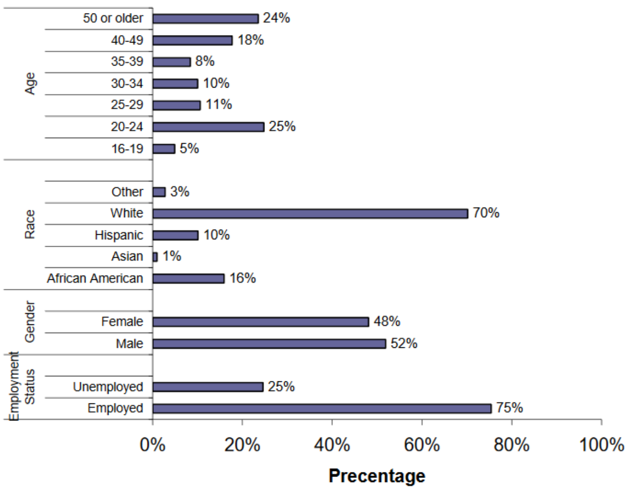
A. COPS Office In-Car Camera Incentive Program

The U.S. Department of Justice’s Office of Community Oriented Policing Services (COPS Office) created the In-Car Camera Incentive Program in 2000. This program has provided over 21 million dollars in assistance to state law enforcement for purchasing the in-car cameras. Before this program, only 11% of highway patrol and state police vehicles have in-car cameras installed. By the year 2002, 72% of the highway patrol and state police vehicles were equipped with video systems, and the number is over 95% by 2018. Through this program we can conclude, there is a tendency for all law enforcement patrol vehicle to have video systems. Also, our project may also benefit from the In-Car Camera Incentive Program.

B. Community Perception

Through research gave to civilian about gauging support for the use of in-car cameras. 94% of the community members stated that they support and approve the use of in-car cameras. Therefore, upgrading current fixed mounted in-car cameras into a high-speed PTZ camera shouldn’t face any resistance from the community member.

GRAPH I
Profile of Public Opinion Survey Respondents



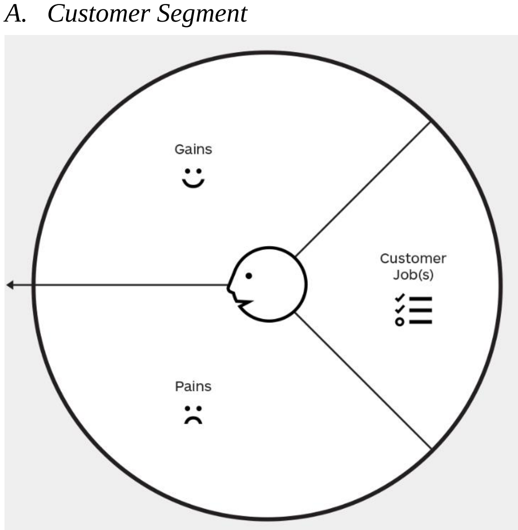
C. *Community Perception*

Although, in-car cameras been available to the North-America market for around 20 years. The mobile PTZ camera is still a new market. One of the competitors is RUGGED CAMS. However, they only focus on industry and construction use, and they don't have any law enforcement application example on their website. Other competitors are all Chinese companies since Chinese police already use mobile PTZ cameras in cities area for around ten years, but they don't have much experience on the highway. However, the current plan is partner with one of the Chinese companies for manufacturing. If we get product available quick enough, we can be the first to the U.S. LE market.

V. VALUE PROPOSITION

This section demonstrates customer's Job, Pain, and Gain, as well as, Solution's Product, Pain relievers, and Gain Creators, in the form of value proposition canvas.

A. *Customer Segment*



Customer Jobs:

1. Video recording while driving.
2. Video recording while stopping.
3. Remote control camera while driving.
4. Remote control camera while parking.
5. Wireless video transmit.
6. Vehicle speed measurement while driving.
7. Vehicle speed measurement while stopping.

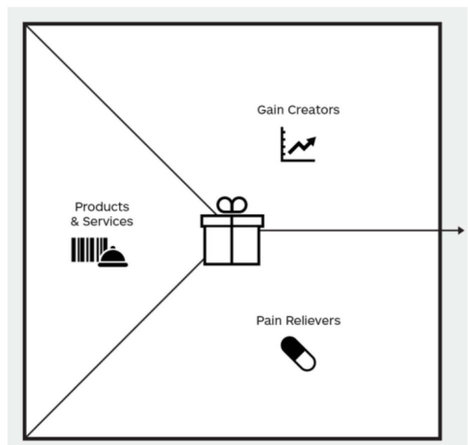
Pains:

1. Camera system halted.
2. Low-resolution video footage.
3. Hard to control
4. Water damage
5. Low definition at night.

Gains:

1. Reliable system.
2. Good view of the surroundings.
3. High-resolution video footage.
4. Automatic control.
5. Energy saving.

B. *Product Segment*



Gain Creators:

1.High elevation location for a better view.
2. Modularized system for different control protocol.
3. Modularized system for the high-resolution camera.
4. Battery protection.

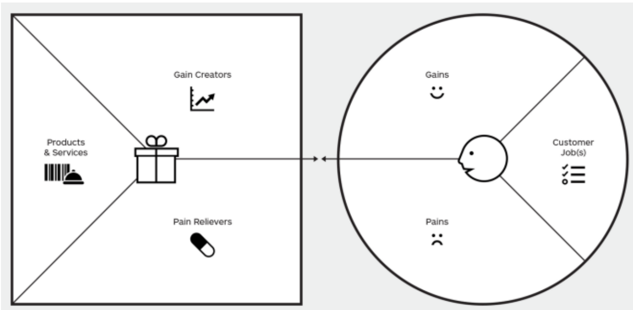
Pain Relievers:

1. Self-test every stating.
2. Modularized system for the high-resolution camera.
3. High-speed stabile control.
4. Waterproof housing.
5. Infrared night-vision.

Products & Services:

1. Root mount easily to use while driving and parking.
2. Wireless video transmit available.
3. Modularized system for flexibility application.
4. Modularized system for different cameras.

C. The value proposition canvas

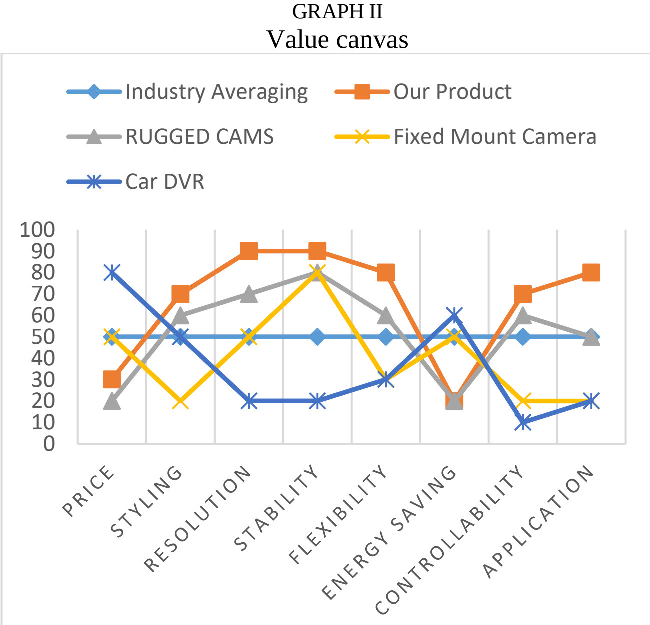


From the two-above section, we can tell that the functions in the Product & Services of the product segment will address the jobs to be down in the Customer Jobs of Customers Segment. Also, the Gain creator mostly matches Customers Gain, and Pain Relievers mostly matches Customers Pain. There is something miss matched, for example, Energy saving, Automatic control, and Wireless video transmit. These still need to solve in the feature research and development.

VI. VALUE CANVAS

In this section, we compare the features of our product and the function of other competitive alternatives using value canvas below.

GRAPH II

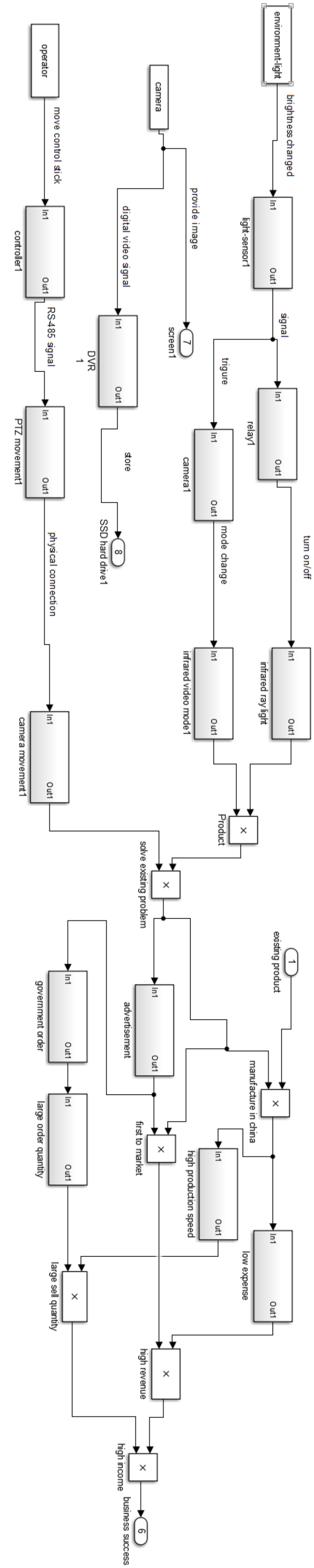


From the graph, we can tell our product has an advantage in Styling, Resolution, Stability, Flexibility, Controllability, and Applications. However, we still need to improve our Pricing and Energy Saving.

VII. FUNCTION DIAGRAMS

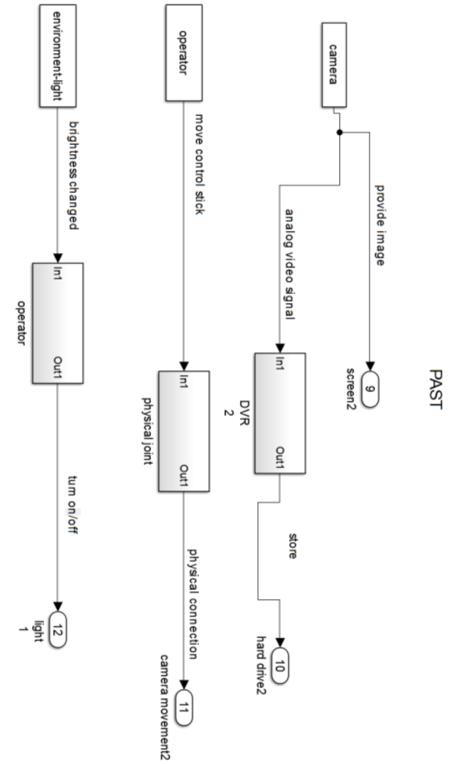
A. Linking cause-effect chains with functions.

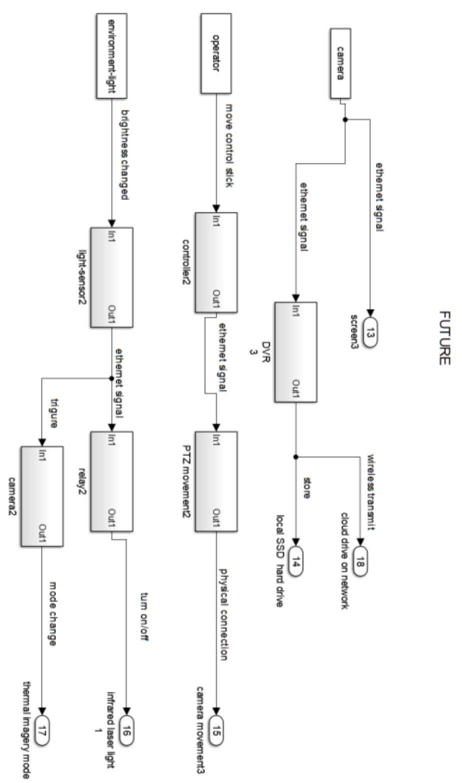
In this section, we show function diagrams for our basic system operations including camera and controllers. Then it is linked to the cause-effect chain for our system's design logic. The process is done through Simulink by MATLAB.



B. Past and future of the system analysis.

In this section, we show the past and future of the system. The main improvement through the years is the signaling transmission from analog to digital then to ethernet. This improvement allows more functions in the system and higher resolution for videos.

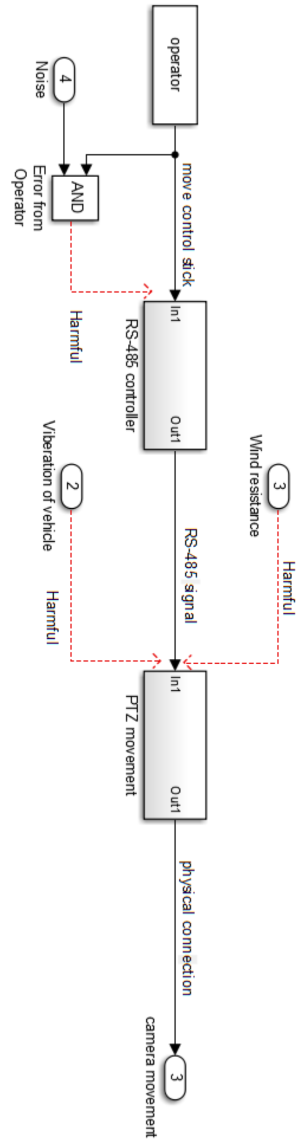




C. Idealization and modification for PTZ control.

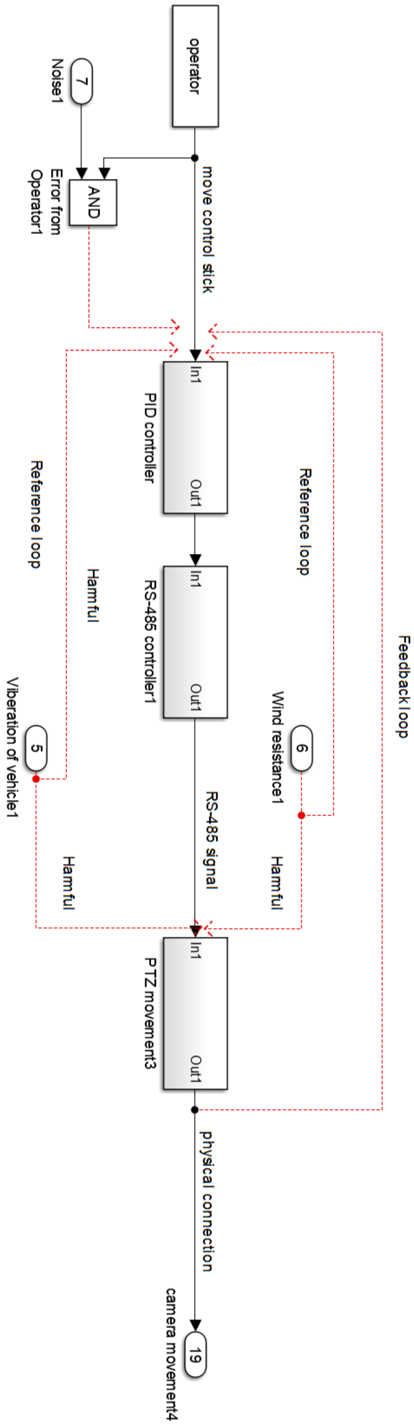
In this section, we are trying to simulate the idealization of the control system. We try to use an idealized PID controller to make the system more stable. We added some known harmful functions to existing first and try to eliminate them.

Control system with harmful input, but without idealization:



Now, we try to introduce a feedback controller or even higher level controller to counteract most of the harmful inputs (including wind turbulence, vehicle vibration, and noise in the system).

Control system with harmful input and idealized PID controller:



VIII. ANALYSIS

From the preview three sessions, we generated function diagrams, cause-effect chain, and harmful input. In this section, we are trying to analyze how physical contradictions underlying the various technical contradictions.

A. *Analysis of simulation.*

The vibration of the vehicle can conduct from the vehicle body to the camera system. This kind of vibration can add hardship for physical joint and moto to move as ordered expected and reduce the accuracy of the system. Although there is no evidence supported that the vibration can cause belt and gear to slip, it is still a possible phenomenon.

Wind is so far the essential contradiction. In this project, we found out as a vehicle is driving at a speed equal to or faster than 80 Mph, the wind will push the camera to its highest angle limit. In this situation, the camera can't get a response to any motion command signal from the controller at all.

After some deeper study, we found out our belt is not strong enough to hold a significant force against the camera body. For example, an operator can stop the moving camera just by a single hand. For the same reason, the camera inner moving parts are not strong enough to handle force created by wind.

IX. FINAL SOLUTION

From the previous research, we located the harmful disturbance by using function diagrams and cause-effect chain. The final solution will be focusing on eliminating these disturbances to make the system more stable.

A. *Reduce vibration from the vehicle*

For the vibration of the vehicle body, we add a cushion between the shelf on the vehicle roof and the camera body. It was made of two sheets of steel plate and connected by a rubber between them.

Fig. 2. The rubber cushion as showing in red.

This reduced most of the vibration and impacted conduct from the vehicle body. Although the vibration is not entirely eliminated yet, the cushion can reduce enough vibration to have a stable view and protect the camera from damage.

B. Improving air dynamic

Due to the equipment limitation of this study, we do not have dynamic data for the current camera been used. We assume a rounder shape of camera housing will reduce the wind resistance. So, we ordered a new housing which is in a better-designed shape.

Fig. 3. The new camera on the left-hand side, old camera on the right-hand side. (The new camera and its carrier vehicle are in a mission as this article been writing, so sorry no better photo is available)

This better shape is much more efficient during a high-speed maneuver, we significantly improved the stability on the vertical axis. But the horizontal axis still has a similar problem.

C. Lock in place

We added a break at each joint of the camera. The breakers only release when a motion signal to that joint is received. This helps the camera to lock in place, to eliminate the camera's motion caused by wind. This feature is helpful while driving through a crosswind area.

D. PID and feedback control

In the featured research, it is possible to introduce a PID closed loop controller instead of directly linear control to make the system more robust and stable. The RS-485 Pelco-D signal is already able to monitor the position of the camera, and it can be used as feedback to the new PID controller.

X. Conclusion

During this paper, we analyze the high-speed stability of a PTZ camera for law enforcement application. Also, some marketing opportunity and value is evaluated. After the project, we can identify two main disturbance (wind and vibration) that affect camera high-speed stability and took action to reduce them. The improved system is stable enough and may add more artificial intelligence feature like visual recognition and auto tracking subject.

Appendix

1) The format of Pelco-P (*hexadecimal bytes*)

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
STX	Camera Address	Data 1	Data 2	Data 3	Data 4	ETX	Checksum

- Byte 1 (STX) - Start of Text, fixed to A0
- Byte 2 (Camera Address) - logical address of the camera being controlled (Address 1 is 00)
- Byte 3 & 6 (Data 1 to 4) - shown below
- Byte 7 (ETX) - End of Text, fixed to AF
- Byte 8 (Checksum) - xOR sum of Bytes 1 to 7

Data 1 to 4 details:

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Data 1	Fixed to 0	Camera On	Auto Scan On	Camera On/Off	Iris Close	Iris Open	Focus Near	Focus Far
Data 2	Fixed to 0	Zoom Wide	Zoom Tele	Tilt Down	Tilt Up	Pan Left	Pan Right	0 (for pan / tilt)
Data 3	Pan speed 00 (stop) to 3F (high speed) and 40 for Turbo							
Data 4	Tilt speed 00 (stop) to 3F (high speed)							

Some other commands

Command	Byte 3	Byte 4	Byte 5	Byte 6
Go to Preset	00	07	00	01 to FF
Set Lens Speed	00	25	00	00 to 33
Alarm Ack.	00	19	00	Alarm no.

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