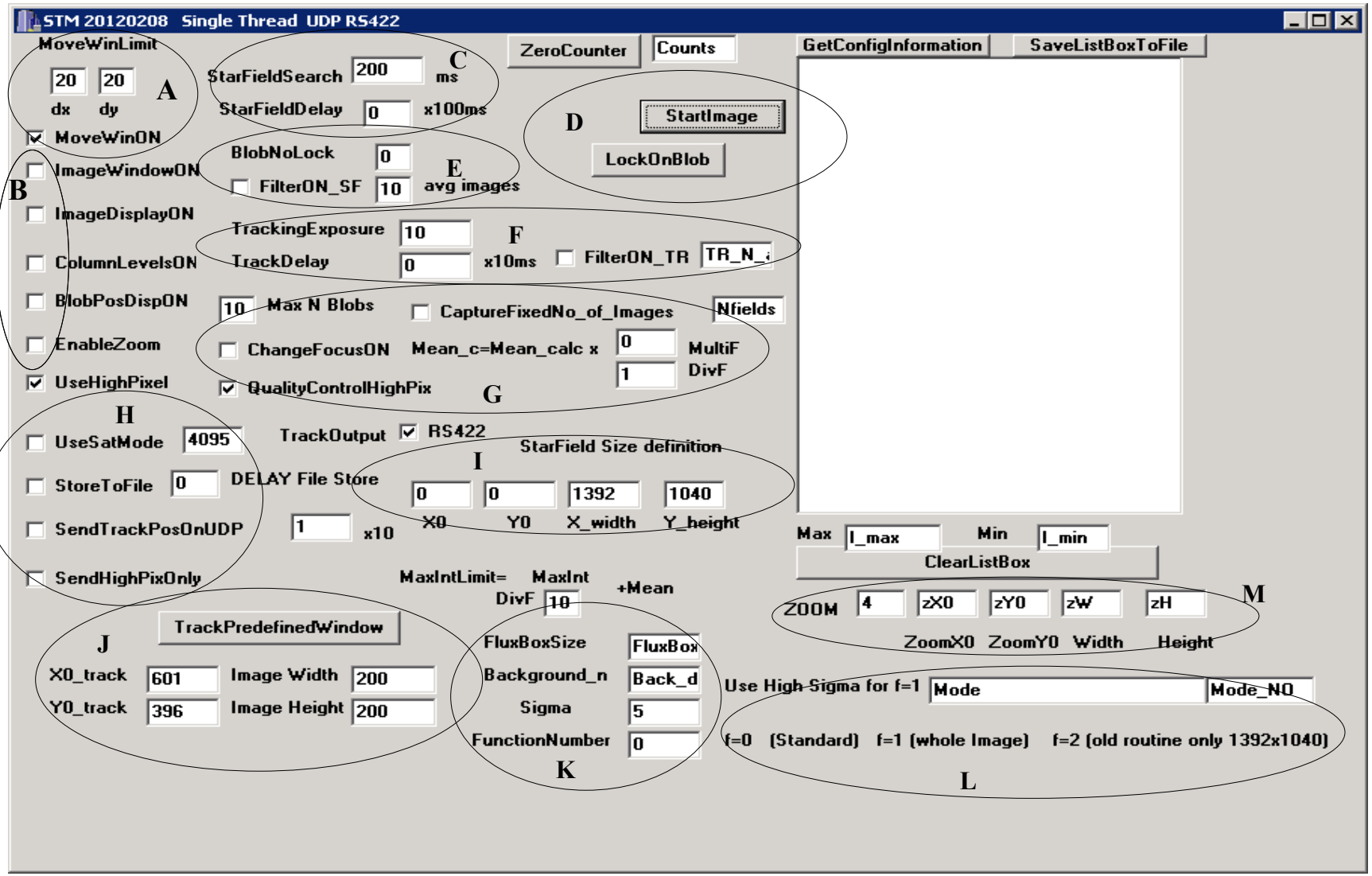
STM and STR on-board and Ground Segment software.

Purpose of this document: to provide a general user guide
Hands on user examples (for operating the software)

Draft 1.0


STM 20120208 Single Thread UDP RS422
MoveWinLimit
20
20
dx
dy
A
StarFieldSearch
200
ms
C
StarFieldDelay
0
x100ms
ZeroCounter
Counts
GetConfigInformation
SaveListBoxToFile
D
StartImage
LockOnBlob
MoveWinON
ImageWindowON
ImageDisplayON
ColumnLevelsON
BlobPosDispON
EnableZoom
UseHighPixel
B
BlobNoLock
0
FilterON_SF
10
avg images
E
TrackingExposure
10
TrackDelay
0
x10ms
F
FilterON_TR
TR_N_
10
Max N Blobs
CaptureFixedNo_of_Images
Nfields
ChangeFocusON
Mean_c=Mean_calc x
0
MultiF
1
DivF
QualityControlHighPix
G
H
UseSatMode
4095
TrackOutput
RS422
StoreToFile
0
DELAY File Store
SendTrackPosOnUDP
1
x10
SendHighPixOnly
StarField Size definition
I
0
0
1392
1040
X0
Y0
X_width
Y_height
Max
I_max
Min
I_min
ClearListBox
MaxIntLimit=
MaxInt
DivF
10
+Mean
ZOOM
4
zX0
zY0
zW
zH
M
ZoomX0
ZoomY0
Width
Height
TrackPredefinedWindow
J
X0_track
601
Image Width
200
Y0_track
396
Image Height
200
FluxBoxSize
FluxBox
Background_n
Back_d
Sigma
5
FunctionNumber
0
K
Use High Sigma for f=1
Mode
Mode_NO
f=0 (Standard) f=1 (whole Image) f=2 (old routine only 1392x1040)
L

Letters indicate GUI position

A group Move Win (tracking mode) the tracking window is adjusted so that the highest pixel is in the centre.
Dx and Dy indicaets threshold for moving window (shold of course be within Win size)
Redefinig a new subwindow requires special calls to the camera driver and slows down the tracking loop considerable. Normal wiggeling should therfore not lead to a new subwindow definition.Define "suitable" dx dy values.

B group Mainly display capabilities. Image window ON should be ON if you want to see anything
Image Display ON dispalys the actual image (rather time consuming)
Columns level on shows maximum value in each column in display
(useful for testing blob algoritms & visualizing background)
Blob positions are displayed and numbered in flux order order 0,1.....
(a flux value is also displaye along with the blob) 0 blob is marked red.
The size of the flux box is defined in **K**

Zoom ON.The image could be zoomed by defining a window **(M)** It's useful for checking focus.

C group Star Field Search exposure time -(ms)
Star Field Delay if we want to slow down the acquiring rate without increasing exposure time (ms)

D group Start Image starts taking images (normally full frame **I)** If some part of the image is disturbed define a smaller image **I** The lock on blob command is issued while star field search images are in progress. It normally identifies the blob with the highest flux. (but it is possible to make it lock on any number in the blob list second strongest in the field etc.)(**E**).The full frame star field acquiring is stopped and a sub window is defined. Tracking starts. There is a time lag (¨1 sec) while changing into tracking mode. This requires good stability and a that blob list is constant. If the image is fluctuating a filtering (average procedure could)be applied **E** ”Filter On avg N images before processing)
The same ”filtering” procedure could also be applied for the tracking loop if badly needed (slows down tracking performance considerable)

F-group Tracking (pretty much the same) Exposure time should of course be as low as possible. **J** size of tracking window (width &height) is is a cruical parameter for performance.

G-group Max N blobs displayed and downloaded. Choose enough to identify star field. Should not be to high (above 25 ?)
Change focus ON NOTE only the STM . During focus ON only focusing commands have any effect. Focusing could be done on the entire image during e-link phase. A limited focusing tool is also available during iridium phase.Downloading and logging max value for the brightest blob in the image. (see GS)

Capure fixed number of images. (a command from ground tells the system to download N images after that the loop stops. Could be useful if we dont't expect that a specific stop command comes through.(fixed number of frames loop)

I-group Star Field window x0,y0 0,0,1392,1040 (default entire image)

H-group use sat mode if one star (tracking star) is much brighter than the rest.I. The software tries to centre on projected coordinates in x and y. (taking the middle point)

Store to file – used for storing files to on-board disk. Mainly for alignmnet calibration (should normally not be used during flight)

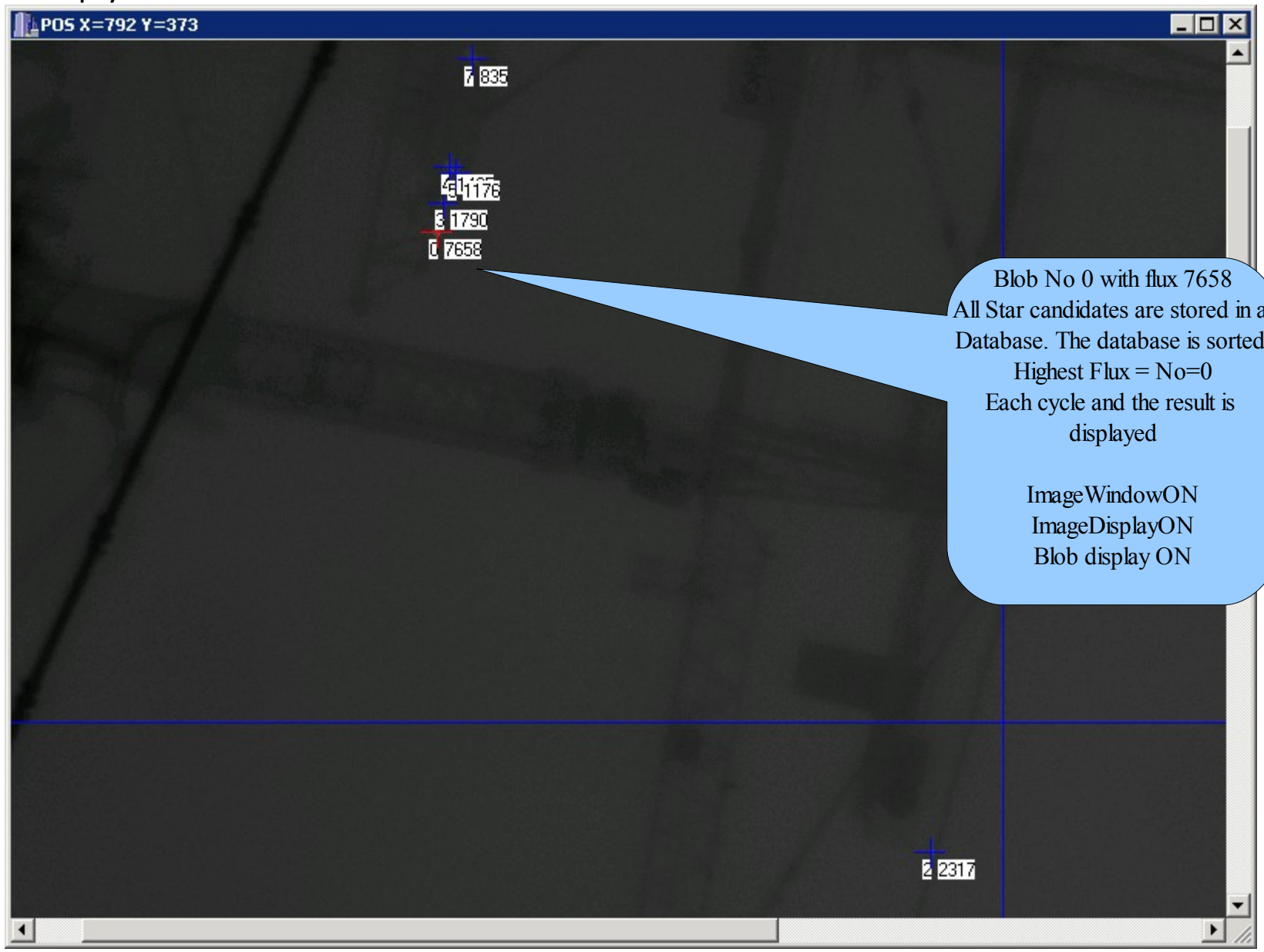
Send track positionOnUDP (to ground) tracking information is send to GS and displayed. This gives a feedback that we are on target.Because of limited bandwidth one could coose to send at a low rate. The UDP to ground rate ios governed by Nx10. N=0 all vill be send. N=1 every tenth value is send Nmax=255 (*10). The rate to the ground is 1: 2550 max

L_group various functions for finding blobs based on slightly different strategies.
F=0 Standard
F=1 Whole image
F=2 Old routine (might be obsolete)

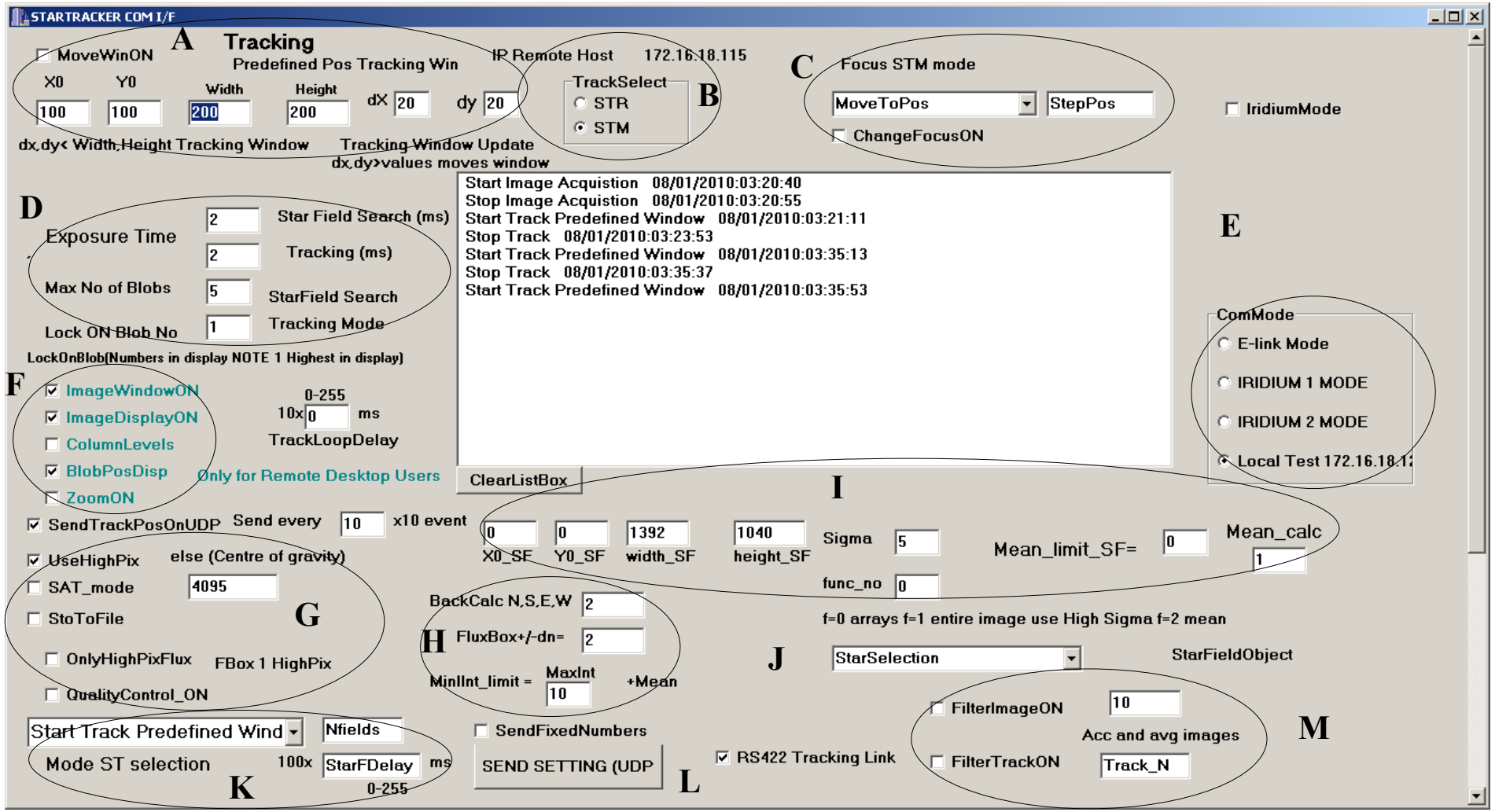
(a more detailed description)

M_group .. Zoom factor (default 4) zX0,zY0 (Zwidth,zheight) for focusing /detailed studying of a spefic area
----------**Note as a default RS422 is checked**. It should only be unchecked in case the RS422 fails. In that case **all tracking commands** will be transmitted through the **general network.**

Blob display



On-board software



Description of the Command GUI. The GS settings image the on-board software settings.

A Tracking move win |ON the window will always try to centre the window. Note a gradient could move the window to the corner. (see system section for a more detailed description) dx,dy (both positive and negative) change to cause an update of window position**.(See p.16)**

B; Most features are the same for the STR and STM but thera are som differences. By changing the status STM <-->STR.

The calibrated centre positions of the cameras are differrent,(see section F) monitoring window..
The IP number to send the data block change **STR** -172.16.18.126 **STM** 172.16.18.115
The fileld of view is different (**B)** monitoring window

C: If **STM** is selected the focusing mode is activated-Clheck**Change Focus ON NOTE ! If in focus mode only focusing commands will have any effect. The type of focusing command is selected C listbox**

Set Max Slew Speed
Home (Init Motor)
MoveToFocus(default) 24750
Go +dPos
Go - dPos
STOP

The focusing command are transferred (as all commands) to the Gondoal by pressing **"SEND SETTINGS TO UDP" (L)**
If we have e-link we wil be able to see effect of the focusing commands. If focusing is required during iridium the focusing tool could be used
Monitoring window (**C)**

D: Exposure time for starField search and tracking. The star field search is of course not very time dependent (if the gondoal is well stabilized).
If the image is highly saturated a shorter exposure should be used. **Max no of blobs** is the maximum number of blobs send down to ground(or displayed) All blobs are sorted in flux order No=0 highest flux N=1 second highest

E: TBD dependent of modem connection the on_board sofware IP outgoing IPnumbers are changed.
E-link, Iridium 1, iridium 2

F; display properties turned off during Iridium (saving on-board computer resources) Mainly used if fast connection for pre-flight calibration purpose and initial calibrations during the e-link phase (STM focusing etc.)

(track loop delay. If the image grabbing would be to fast for the system. The image

G: Send track position on UDP. The track position is always transferred to the ACS. Normally this is done through a RS422 link (alternatively as an UDP block to the ACS), As an option it could also be downloaded to the **GS.** It's send to the ground segment as an UDP block. This will produce a visual feedback on the monitoring window. The yellow dot (only one) should be close to the red representing the guide star. This UDP is only for confirmation and could therefore be send at lower frequency. Send every 10*10 means that track positions will be downloaded to the ground every hundredth.If you enter **0** the system will try to to send it with the same rate to the ground as the actual track rate.

H: Fluxboxsettings +/- dn 2 defines 5x5 fluxbox. Used for sorting blobs. The background is calculated by using value in four directions outside the fluxbox. (median value)

MaxInt Limit uses the Maximum Integer value in the ltracking-box to define a **lowest acceptable limit** for pixel values to be considered to be a part of the star. (the nearest neighbour of the maximum pixel) This serves as a filter discarding all values below this limit as part of the noise. This is only used if the **quality control check** is turned **on.** The default value says nearest neighbour pixels should have values higher than the sum of : mean(of trackbox) and one tenth of the maximum value of trackbox. This is used to provide a reasonable fast filter (based) on the highest track box values.The mean is calculated in parallell while searching for the highest pixel value.

I: Star field search window (default full frame) **1392 x1040.**If some part of the image would be disturbed by stray light, bad pixels..., a **subwindow** could be used for the star identification.(this will also improves the cycle time of the star loop).

A sub-window could therefore also be useful if a faster feedback is wanted. (The gondola is not fully stabilized). Three different routines are used for star field identification (number 3 might be obsolete but have I kept it **NOTE it does not work with a sub-window**) Routines 1 and 2 have a different approach (see for detailed description)

Mean_limit_SF=mean *(multiplication factor /division factor) By combining these two it's possible to fine adjust the mean value calculated for the selection criteria. An multiplication factor of 11 and division factor of 10 will increase the calculated mean value with 10%. This imposes a slightly harder constraint for star selection. (sse for further information)

The sigma value is used a minimum criteria for selecting a star. (Flux_min=sqrt(median_back)*Sigma

Increasing the sigma value will of course put a harder constrain on star serlection.

J Star selection in order to make operations smooth default objects could have been included in the source code. The RA DEC values are set in monitoring window (**E)**i f the combobox star selection is changed. If a target object is not in the list it's always possible to enter target coordinates.

CAPELLA-a
GAMMA-CAS
VEGA
DENEB
Crab
Cygnus X
.....

K: Main mode selection

The tracking could be initiated in <u>two</u> ways. A,B

<u>A: Lock on Blob</u> (Image Acquisition is running) (semi automatic mode) NOTE it's started without first stopping the ImageAcquistion

<u>B: Stop image acquisition</u> Starttrack Predefined Window (A) command window

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<u>Start Image Acquistion</u> The star field identification loop is started

<u>Stop Image Acquistion</u> Stop image acquisition of the star field

<u>Start Track (Lock on Blob)</u> The software will try to selected lock a tracking window on blob No (flux order) (D) command window

<u>Stop Track</u> Will stop tracking regardless on how it was initiated !

<u>Start Track Predefined Window</u> The track window is define through predefined settings (A) the ImageAcquistion <u>should not be running</u>
The monitoring coordinate system and the on board system are defined in the same way. The window coordinates of the monitoring window could therefore be use to define appropriate window (see
(See examples)

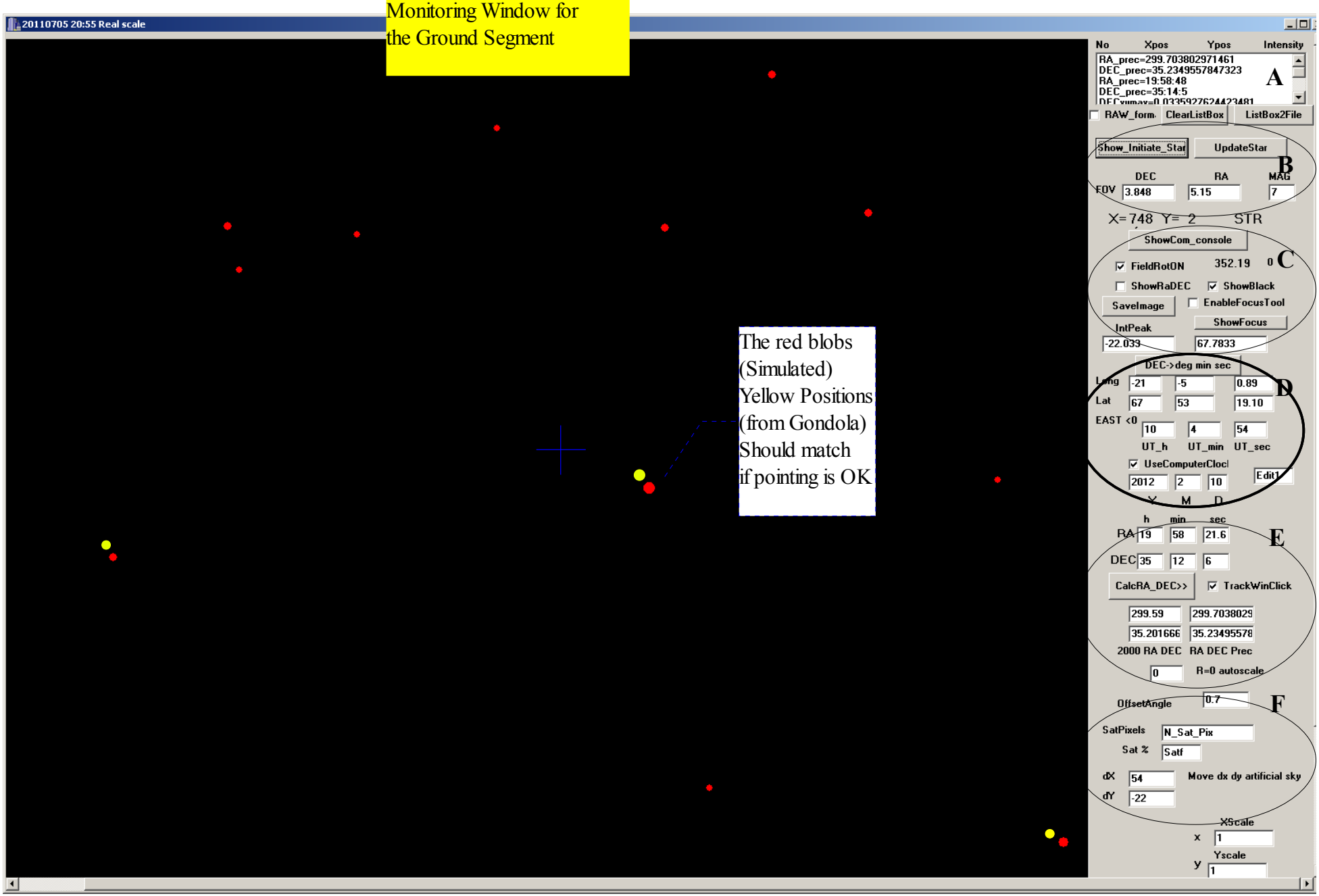
after selecting the desired mode press

L: SEND settings UDP transfer all settings and take the selected action Start/Stop etc

M: If the images are very noisy it is possible to accumulate and average a number of images before doing image processing. Identifying blobs, finding tracking pixel....

Filter On image (filter star field identifying)
Filter track (filter track)

NOTE ! This should only be use absolutely necessary -it will degrade performance considerable !


Monitoring Window for the Ground Segment
20110705 20:55 Real scale
The red blobs (Simulated) Yellow Positions (from Gondola) Should match if pointing is OK
No Xpos Ypos Intensity
RA_prec=299.703802971461
DEC_prec=35.2349557847323
RA_prec=19:58:48
DEC_prec=35:14:5
A
RAW_form
ClearListBox
ListBox2File
Show_Initiate_Star
UpdateStar
B
DEC
RA
MAG
FOV
3.848
5.15
7
X= 748 Y= 2 STR
ShowCom_console
FieldRotON
352.19
0
C
ShowRaDEC
ShowBlack
SaveImage
EnableFocusTool
IntPeak
ShowFocus
-22.039
67.7833
DEC->deg min sec
Long
-21
-5
0.89
Lat
67
53
19.10
D
EAST <0
10
4
54
UT_h
UT_min
UT_sec
UseComputerClock
2012
2
10
Edit1
Y
M
D
h
min
sec
RA
19
58
21.6
E
DEC
35
12
6
CalcRA_DEC>>
TrackWinClick
299.59
299.7038029
35.201666
35.23495578
2000 RA DEC
RA DEC Prec
0
R=0 autoscale
OffsetAngle
0.7
F
SatPixels
N_Sat_Pix
Sat %
Satf
dX
54
Move dx dy artificial sky
dY
-22
XScale
x
1
Yscale
y
1

Monitoring Window

A: Information and logging window. By checking raw positions will be stored in columns without text. (useful for storing log to disk & plotting software. ListBox2File will store info to file.

B: Show initiate star will produce a subset of the main star database. The subset is based on FOV (dRA,dDEC) and centre coordinate of desired sky position (prec. to current date). **(E).** Once the subset has been defined for that particular position of the sky (take some time) there is no need to go through the entire database each time. By pressing **updatestar** the sub-database produces what the sky should look like at a given time **(UT)** and position (**latitude and longitude ,GPS)** of gondola. The computer clock could generate **UT. Check that it's correct !** The position of the gondola **(D)** (changing rather slowly) is for the moment entered manually in the GUI. **(TBD)**

C; By pressing update star the star will be rotating around the centre position(field rotation) to produce the present sky. The field rotation is displayed **0-360 deg if Field rotation turned on.** RA & DEC information could be turned on

Enable focusing tool (a rather special mode). If we need to refocus during the iridium phase it's possible to download brightest blob and display the highest pixel value as a function of focus values.(Show Focus shows a historic plot of highest pixel values), During the e-link phase we hope to focus, by looking at images directly through remote desktop.

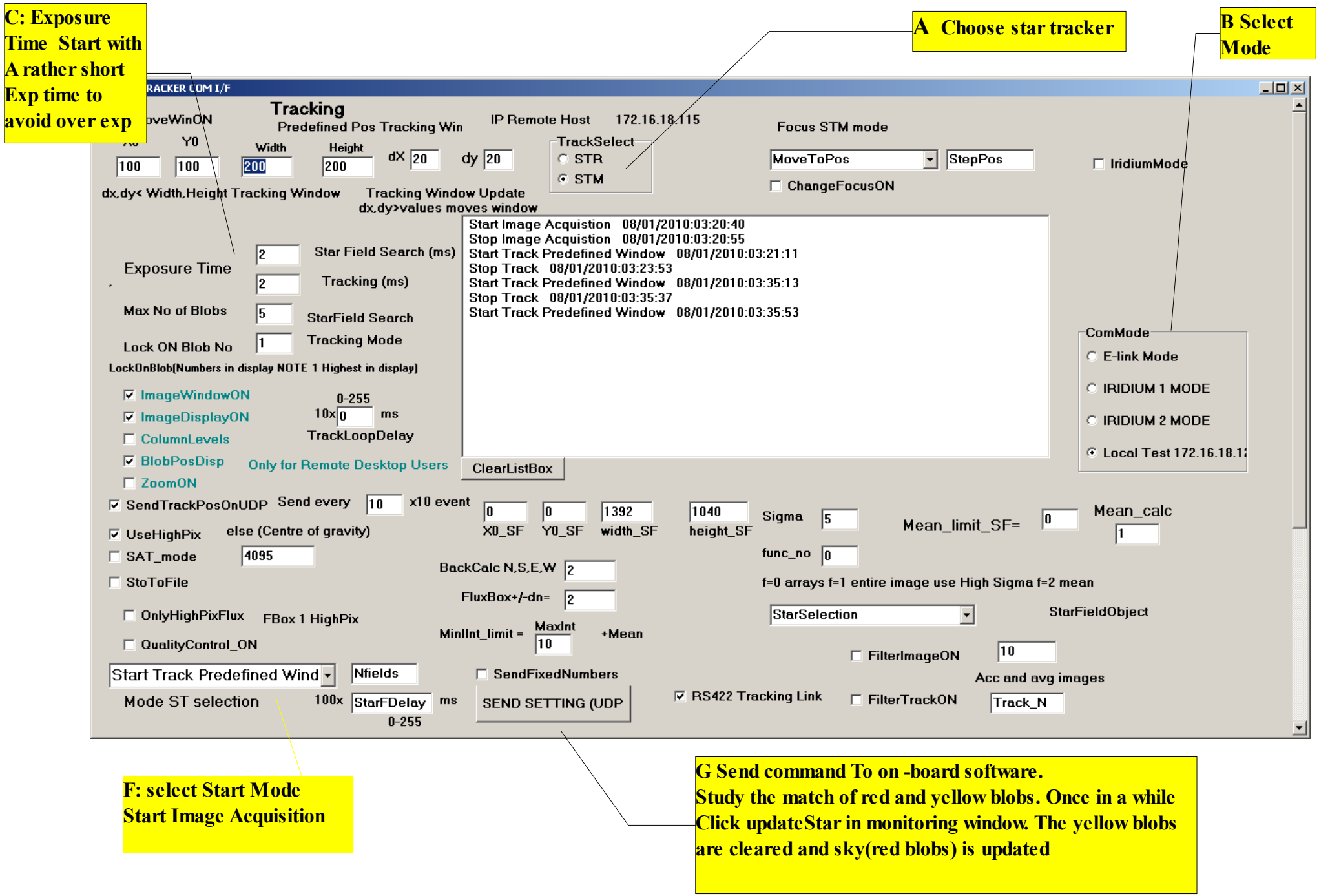
D: Latitude Longitude input. Note the definition of Longitude East <0 !

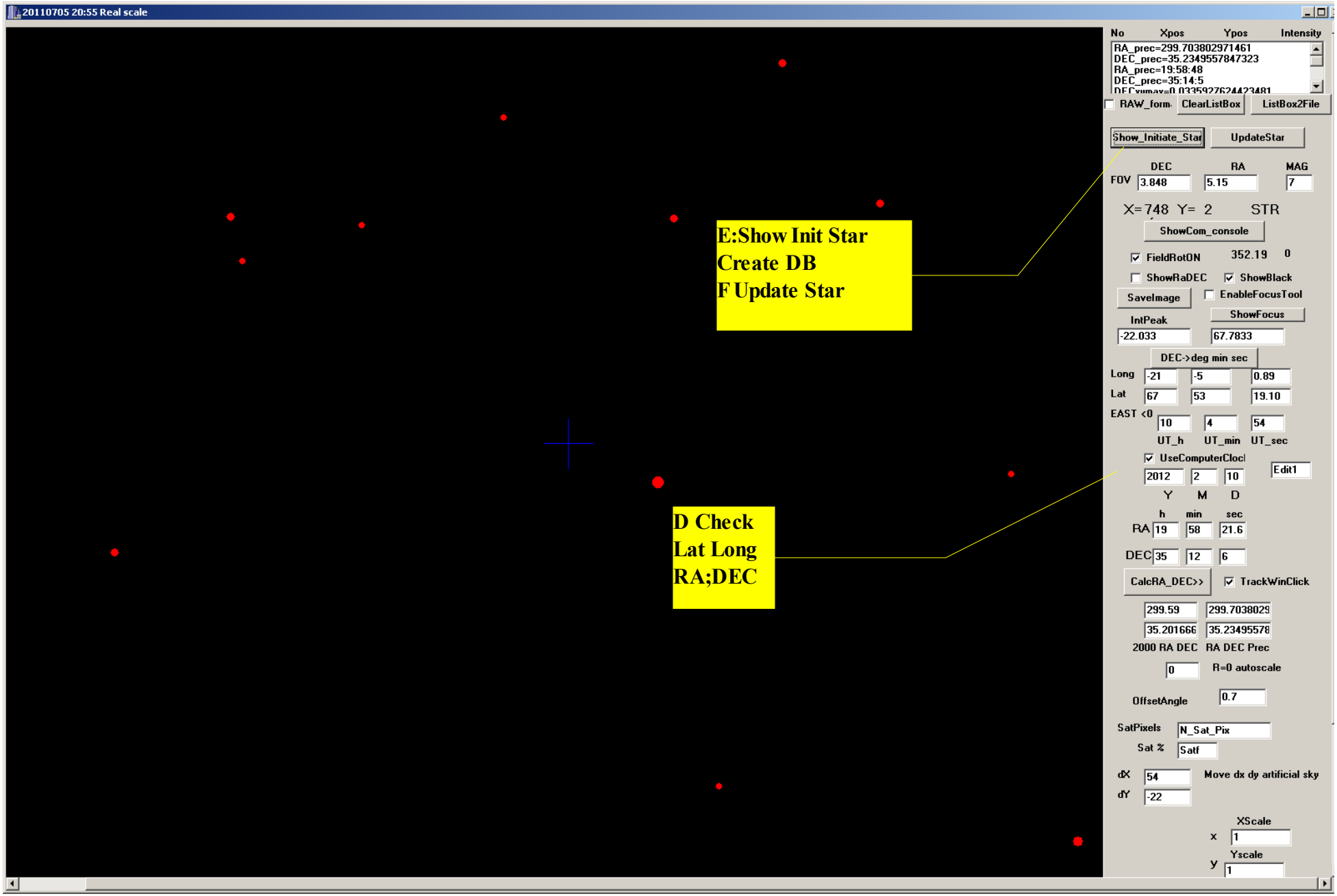
E: RA DE C input 2000 coordinates.! These coordinates could also be defined in StarSelection (listbox) Command Window. (manually entered values in "E" will overide the selection in the command window until listbox is changed in the command window.

F:If we have **constant offset angle**. Camera not perfectly aligned. The value could be changed to make a better match of red and yellow blobs. Satpixels gives a hint on exposure time and problems with the image. **Dx DY offset positions for the cameras STR and STM (they normally don't match perfectly) The predefined values (calibrated on ground) should change if we switch between STR and STM (command window).**

These values might need recalibration during flight !

Scaling effects could also be be accounted for -Xscale Yscale =1 (no change)


C: Exposure Time Start with A rather short Exp time to avoid over exp
A Choose star tracker
B Select Mode
RACKER COM I/F
Tracking
oveWinON
Predefined Pos Tracking Win
IP Remote Host
172.16.18.115
Focus STM mode
Y0
Width
Height
dX
dy
TrackSelect
STR
STM
MoveToPos
StepPos
IridiumMode
ChangeFocusON
dx,dy< Width,Height Tracking Window
Tracking Window Update
dx,dy>values moves window
Start Image Acquistion 08/01/2010:03:20:40
Stop Image Acquistion 08/01/2010:03:20:55
Start Track Predefined Window 08/01/2010:03:21:11
Stop Track 08/01/2010:03:23:53
Start Track Predefined Window 08/01/2010:03:35:13
Stop Track 08/01/2010:03:35:37
Start Track Predefined Window 08/01/2010:03:35:53
Exposure Time
Star Field Search (ms)
Tracking (ms)
Max No of Blobs
StarField Search
Lock ON Blob No
Tracking Mode
LockOnBlob(Numbers in display NOTE 1 Highest in display)
ComMode
E-link Mode
IRIDIUM 1 MODE
IRIDIUM 2 MODE
Local Test 172.16.18.1
ImageWindowON
ImageDisplayON
ColumnLevels
BlobPosDisp
ZoomON
0-255
10x
ms
TrackLoopDelay
Only for Remote Desktop Users
ClearListBox
SendTrackPosOnUDP
Send every
x10 event
X0_SF
Y0_SF
width_SF
height_SF
Sigma
Mean_limit_SF=
Mean_calc
UseHighPix
else (Centre of gravity)
SAT_mode
StoToFile
func_no
BackCalc N,S,E,W
FluxBox+/-dn=
f=0 arrays f=1 entire image use High Sigma f=2 mean
StarSelection
StarFieldObject
OnlyHighPixFlux
FBox 1 HighPix
QualityControl_ON
MinIInt_limit =
MaxInt
+Mean
FilterImageON
Acc and avg images
Start Track Predefined Wind
Nfields
SendFixedNumbers
Mode ST selection
100x
StarFDelay
ms
0-255
SEND SETTING (UDP
RS422 Tracking Link
FilterTrackON
Track_N
F: select Start Mode Start Image Acquisition
G Send command To on -board software.
Study the match of red and yellow blobs. Once in a while Click updateStar in monitoring window. The yellow blobs are cleared and sky(red blobs) is updated


20110705 20:55 Real scale
E:Show Init Star
Create DB
F Update Star
D Check
Lat Long
RA;DEC
No
Xpos
Ypos
Intensity
RA_prec=299.703802971461
DEC_prec=35.2349557847323
RA_prec=19:58:48
DEC_prec=35:14:5
RAW_form
ClearListBox
ListBox2File
Show_Initiate_Star
UpdateStar
DEC
RA
MAG
FOV
3.848
5.15
7
X= 748 Y= 2
STR
ShowCom_console
FieldRotON
352.19
0
ShowRaDEC
ShowBlack
SaveImage
EnableFocusTool
IntPeak
ShowFocus
-22.033
67.7833
DEC->deg min sec
Long
-21
-5
0.89
Lat
67
53
19.10
EAST <0
10
4
54
UT_h
UT_min
UT_sec
UseComputerClock
2012
2
10
Edit1
Y
M
D
h
min
sec
RA
19
58
21.6
DEC
35
12
6
CalcRA_DEC>>
TrackWinClick
299.59
299.7038029
35.201666
35.23495578
2000 RA DEC
RA DEC Prec
0
R=0 autoscale
OffsetAngle
0.7
SatPixels
N_Sat_Pix
Sat %
Satf
dX
54
dY
-22
Move dx dy artificial sky
XScale
x
1
Yscale
y
1

If we have a reasonable good agreement (yellow dots and red) Proceed to with tracking mode.

In the command window. (K) choose

Option A: Lock on blob. Default the software tries to lock on bob 0.(highest intensity) If you know that the tracking star is number two in intensity choose (D) 1. (Lock ON blob No - 1).

It is possible to check that the desired tracking star has a corresponding intensity number (using the monitoring window)
NOTE if the image is disturbed (and/or) the two stars have almost the same intensity it's a risk that the locking method will fail.

If the field contains a well defined tracking star.

Lock On Blob - SEND SETTINGS (UDP) (click) (The software on board software tries to lock on blob)

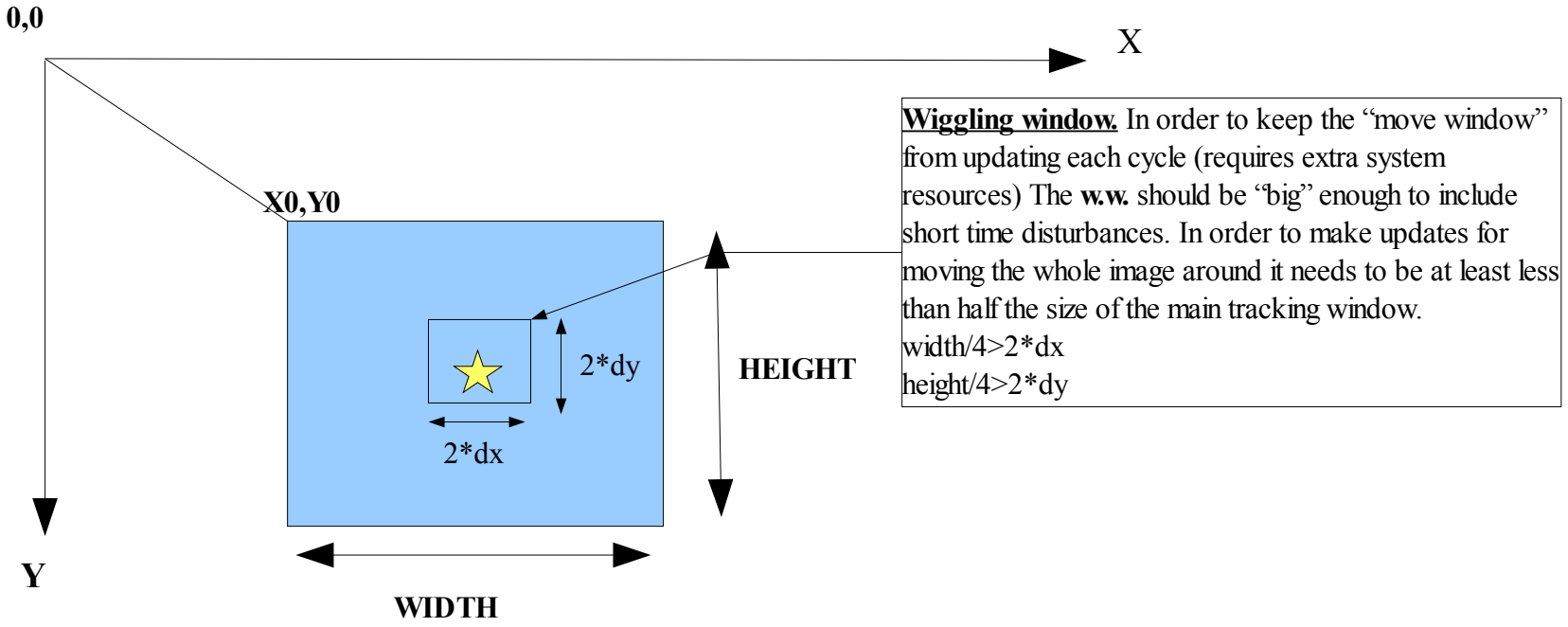
[Lock on blob – will trigger the following command sequence On-board software]

L1: The blob no intensity selected stores the x and y coordinates
L2. The Star Field thread is stopped.
L3: Qcam camera drivers are stopped
L4: The tracking thread is initiated the X and Y coordinates (L1) are used two define the position of a sub-window (tracking window) Default 200x200 in command window. The setting are transferred to the camera using Qcam drivers.
L5:The tracking thread is started with the above settings.

FEEDBACK: IF the SendTrackPos on UDP is checked in the command window. The tracking thread will send the tracking position to the ground. In the monitoring window the yellow blob, representing the tracking should follow the simulated sky (red blob). The monitoring window is updated by clicking "Update star" (B). The simulated sky is updated and the yellow blob history is cleared by clicking- "Update star" in the command window.

Option B: "Predefined tracking window"

Assuming that the Star Field is downloading and that the yellow an red match. Identify the tracking star (normally) the biggest red (and yellow blob). By moving the cursor across the monitoring window. The pixel coordinates x,y is displayed to the left in the same window. (B monitoring window) In the command window, you could define the tracking area (window). NOTE X0,Y0 defines the upper left corner of the window



Coordinate system pixel definition (same definition Ground Segment and On-board software)
By monitoring the behavior of the tracking star makes it possible to select appropriate window sizes. This will always be trade-off between performance (smaller window) and safety margins. Increasing the window size(s) will also

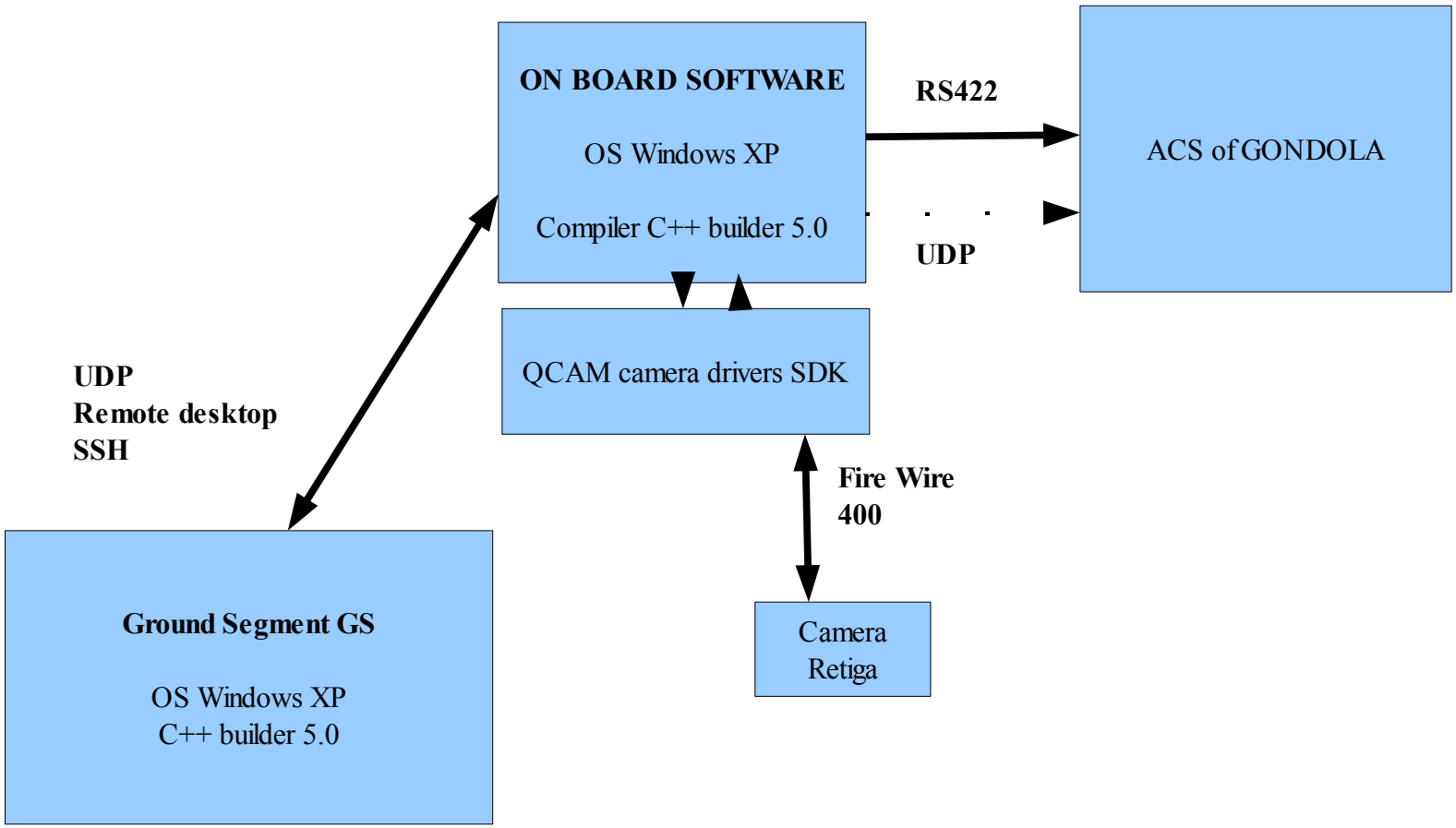
Stop Tracking **“SEND SETTINGS (UDP) (click) Stops the tracking**

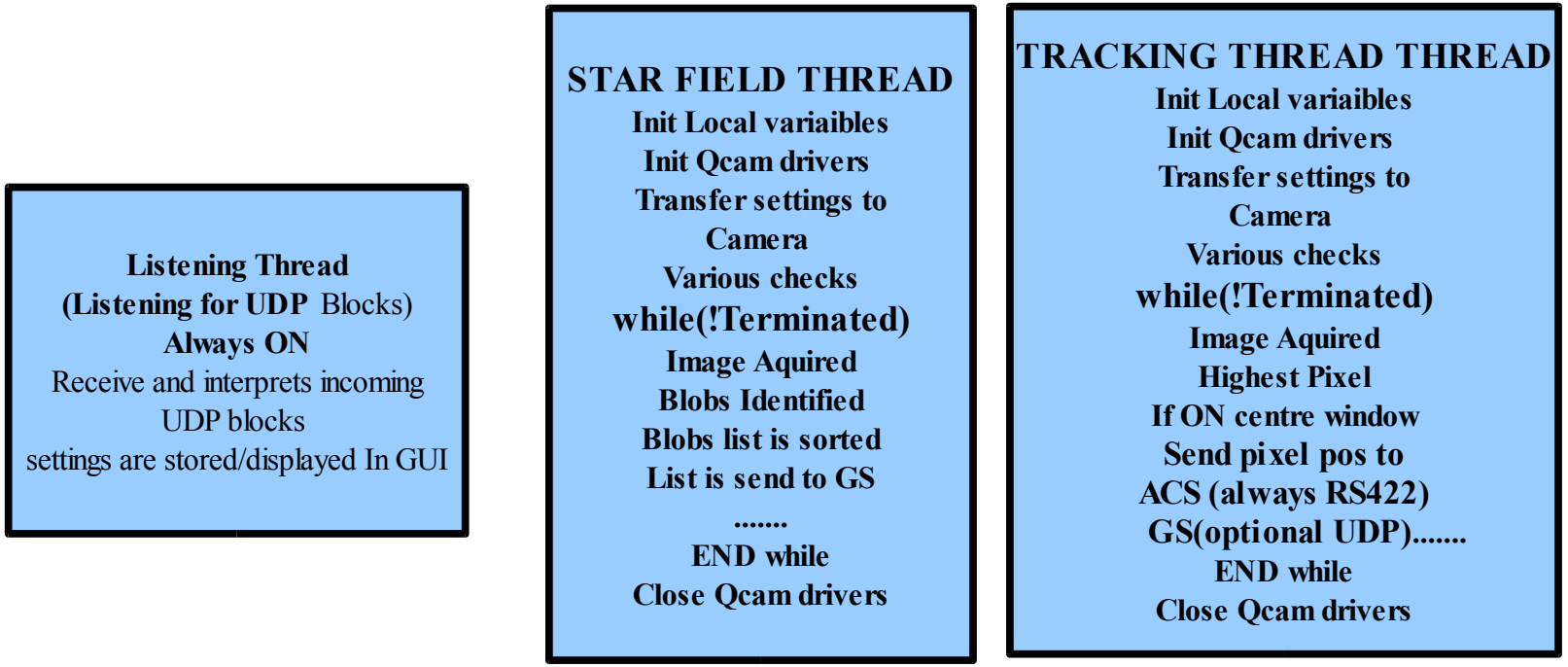
Start Track Predefined Window **“SEND SETTINGS (UDP) (click) Starts tracking (tracking area defined in command window)**

NOTE ! If Moving window is checked the window will automatically follow (center window around the highest pixel in the window) If this works OK. I stability and tracking works without any major disturbances the tracking window will follow a circle around the center position. *field rotation” The red blobs in the monitoring window will of course follow the field rotation (normally rather slow) By pressing the “update star” once in a while to check that the red and yellow blob representing the tracking star match. NOTE if mowing window is OFF ,new positions for the tracking window need to be uploaded to the system once in a while. This option could be used if stability of system is bad.

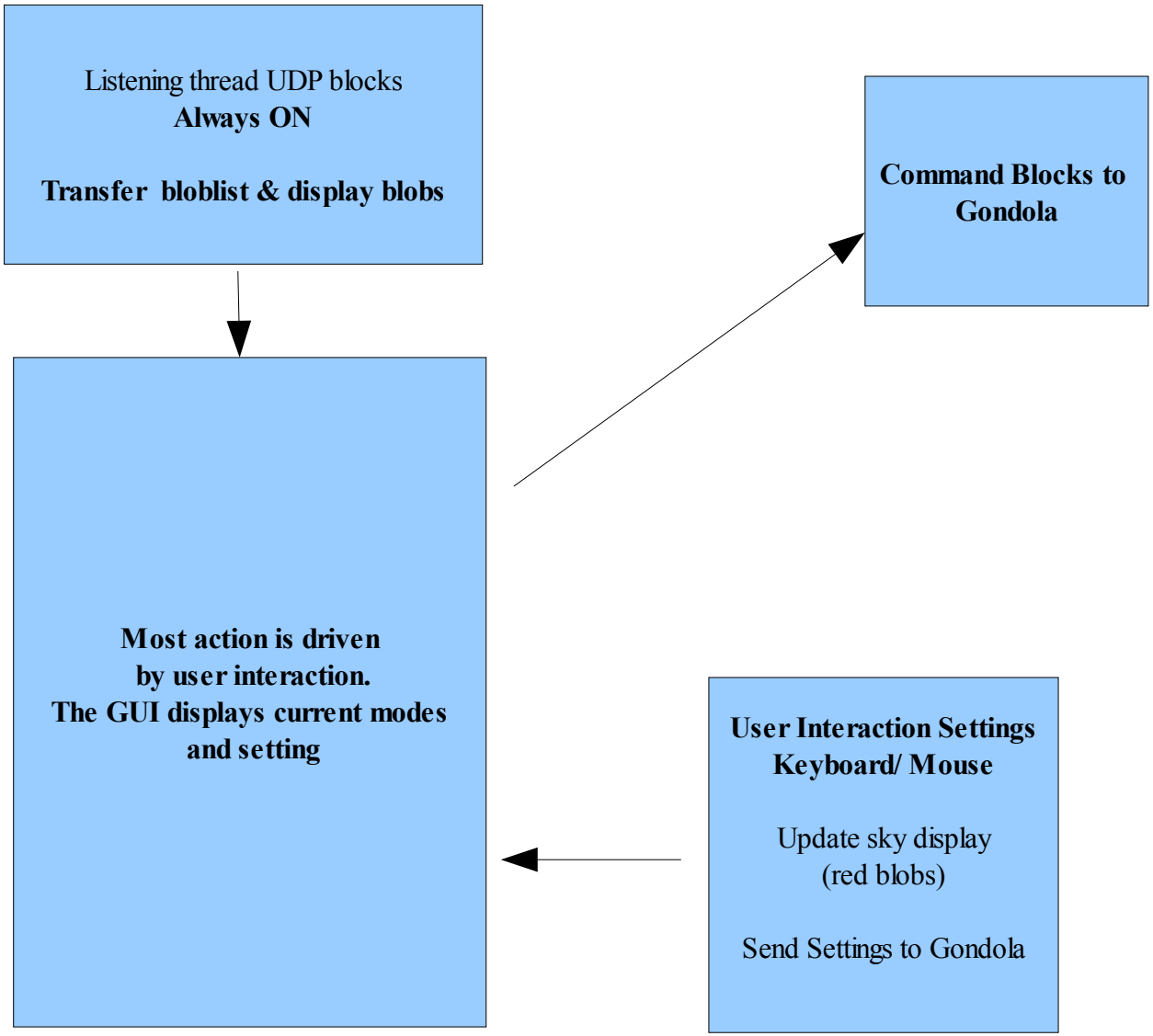
PART 2 under the hood.

Purpose: to provide a overall understanding on how the tracker system works.



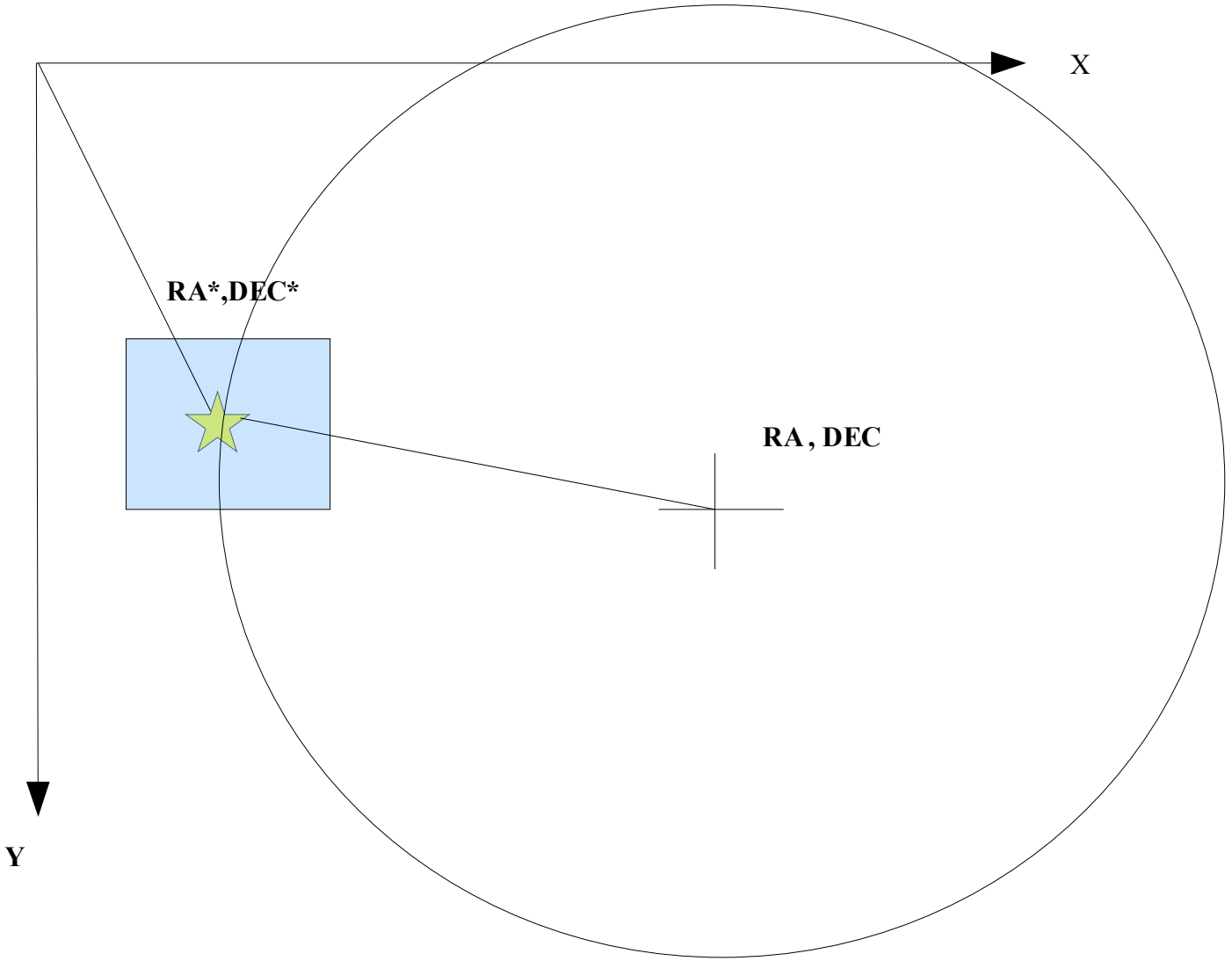


Outline of the on-board software .....


Listening thread UDP blocks
Always ON
Transfer bloblist & display blobs
Command Blocks to Gondola
Most action is driven by user interaction. The GUI displays current modes and setting
User Interaction Settings Keyboard/ Mouse
Update sky display (red blobs)
Send Settings to Gondola

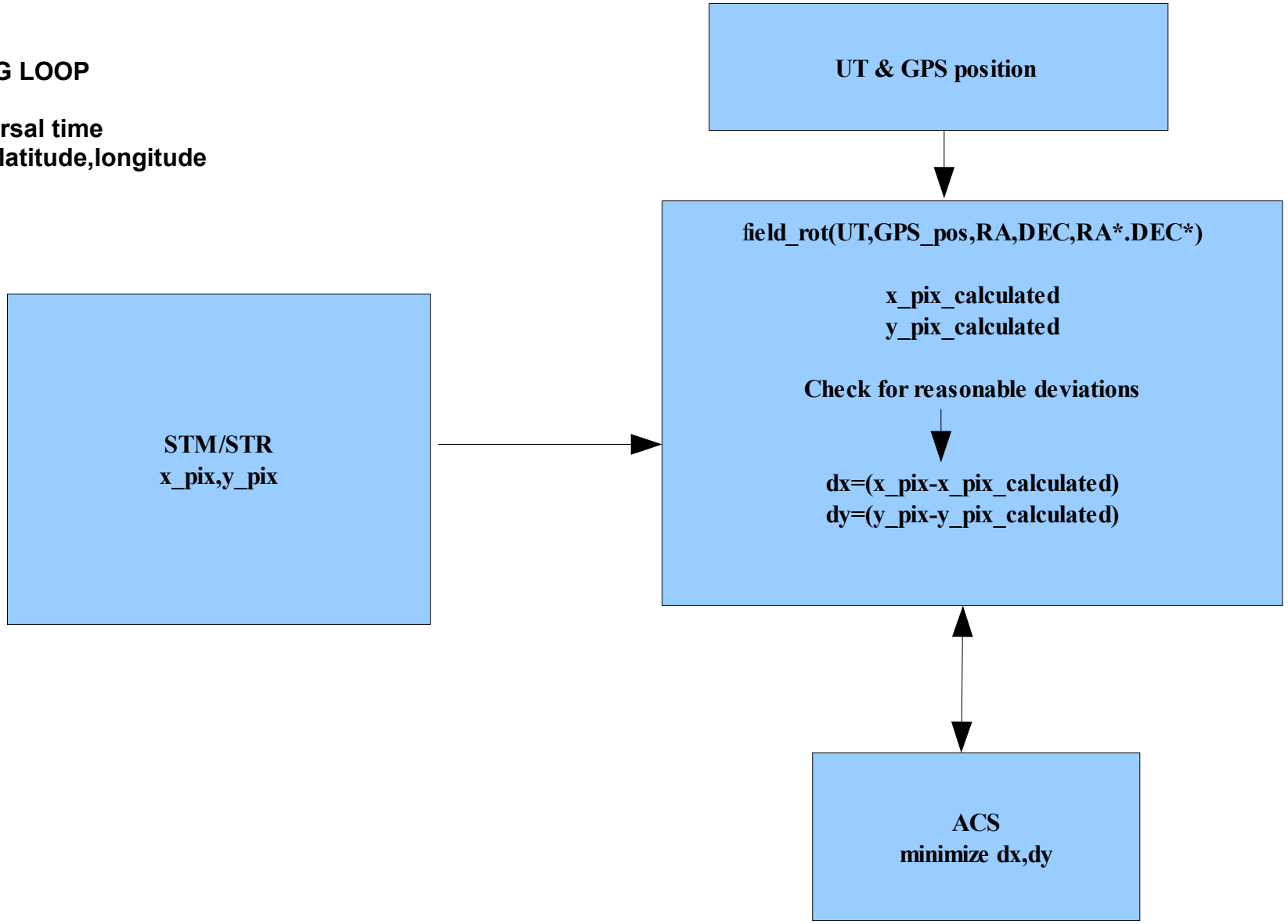
TRACKING & ACS (THEORY)

If we manage to stabilize the system around RA,DEC center position (TARGET !), RA*,DEC* represents position for tracking star. Note the tracking star (RA*,DEC*) will rotate around the center position. NOTE the tracking star should be chosen with care so that it is well within the field of view for the star tracking camera, during the duration of the observation.



TRACKING LOOP

UT= universal time
GPS pos. latitude,longitude



Blob Finding Function.....

For a full understanding please read the source code. A full description in writing would be very hard.

A:The most basic 1 -dim criteria for identifying a star would be f(n) >(f(n+1) and f(n-1)) A condition could also be imposed by f(n+1) and f(n-1) should be above some basic noise level.

Function number 1 projects the maximum levels into two arrays - max:row array and max column array. The corresponding y and x coordinate are also stored. This reduces the full image to two arrays 1392 and 1040. Searching for the criteria A is much faster. In order two be a star candidate should match (**A) the row and column criteria.** The software also store additional sub-lists for the columns and row to account for multiple stars in the same column (row). The resolution of the method is three pixels-the lowest possible value to identify a star. If the star would be a perfect point, the method would fail. A gradient across the image could make the estimate of an overall background hard. Lowering the (**l , Mean_limit_SF p . 0= no mean criteria**) will increase sensitivity for star detection. All the stars candidates are stored in a database and corresponding flux boxes are calculated. This is done after every image has been acquired. The database is also **sorted in flux-box order**. This also provides an additional filtering, A higher flux box is more likely to represent a star. The flux box value is scaled and send to the GS along with the x,y values. The function also checks a hot pixel map excluding known hot pixels. A saturated star is being defined by the centre value of dx - saturated values dy saturated values

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Function number 2 goes through the entire image and locally (for each point) tries to determines if the x,y is likely to be as star. The background estimate is estimated locally and makes the method better for a gradient disturbed image.

Basic selection criteria: as (A)but more points included. f(n-3),f(n-2),f(n-1) f(n) f(n+1),f(n+2),f(n+3) in x and y direction. Should be a decreasing function from centre point.

Function number 3 old (only full frame 1040x1392) uses the mean of entire image (not poosible to change cut-off values)

The code overview .....

All software necessary to compile the source code are installed on each computer GS and Flight (Flight spare)
Compiler C++ Builder 5.0
Asynch Professional
QCAM SDK & QCAM drivers

Qcam drivers using a header file to link C++ files to the compiled Qcam drivers (no source code)
QcamApi.h I/F -defines functions headers used throughout the program to communicate directly with the camera.

Main software units	Code Lines	
ON-board software		**Main features**
Unit1	~ 900	Handeling cmd blocks and GUI controls
ImageDisplay Unit	~90	GUI image display
Tracking loop	~650	Different modes of operation (tracking)
ImageCalc_buff	~1300	Star Finding Routines

GS Ground Segment		
Unit1	~1150	Main GUI display
Unit2	~750	Cmds / GUI for changing settings (cmd block definition of)
Functions	~ 550	Mathematical transformations etc (for calculating the sky – the appearance)