Automated Detection of Lunar Impact Flashes

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Purpose and History

- **NASA/MSFC sponsored effort to develop impact detection capability**
  - *Reliable and robust*
  - *PC based non-real-time processing*
  - *Work with AVI files saved to hard disk from pre-recorded video tapes*
  - *Available for use by amateur lunar observers to observe/confirm impacts*

- **Historical Development**
  - *Request from Dave Dunham to process the 1999 Leonid impact tapes*
  - *More proof of concept for detection that turn-key processing*
  - *Leveraged off real-time meteor detection software (MeteorScan)*
  - *Real-time Mac system detected twice the impacts found by eye !*
  - *In 2006 ported from Mac to PC with NRT AVI file processing*

Detection of Lunar Impacts

Characteristics

- Short transient events
  - *1 to 2 video frames*
  - *Limited temporal signature*
- Circular spatial extent
  - *Few pixels due to sensor PSF*
- Imaged on dark lunar face
  - *Higher contrast in visible light*

Software needs to be robust for amateur use

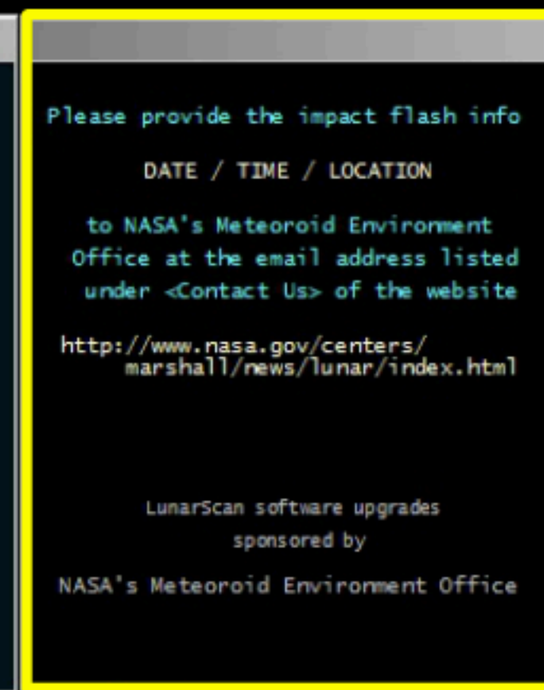
Challenges

- Motion of FOV
  - *Poor tracking & polar alignment*
  - *Telescope repositioning*
  - *Wind and mount vibration*
- Difficult to register frames
  - *Low surface/sky contrast*
- Bright limb encroachment
  - *Optical train reflections*
  - *Huge #s false alarms*
- Star scintillation
  - *Mimic impact flashes*

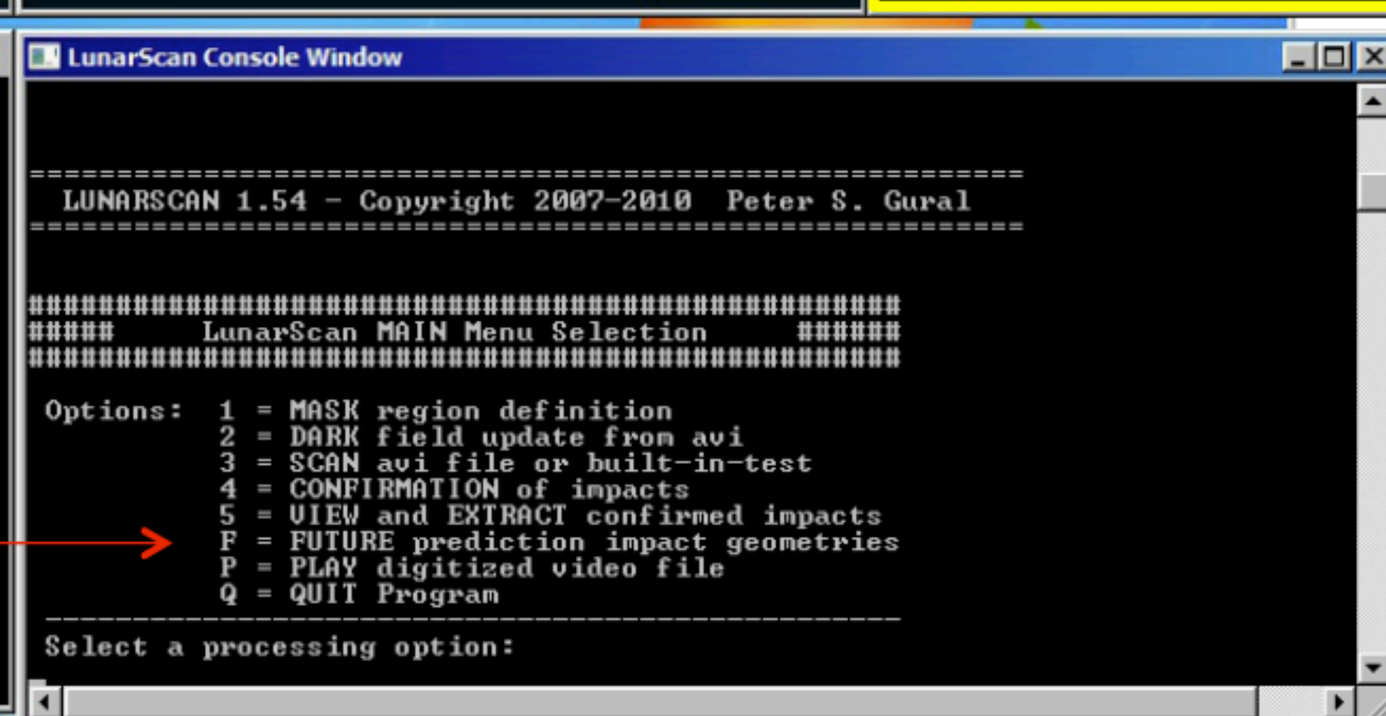
Start Up Menu Options

Double click LunarScan153.exe to launch app.

Where to send results.



For impact predictions type F



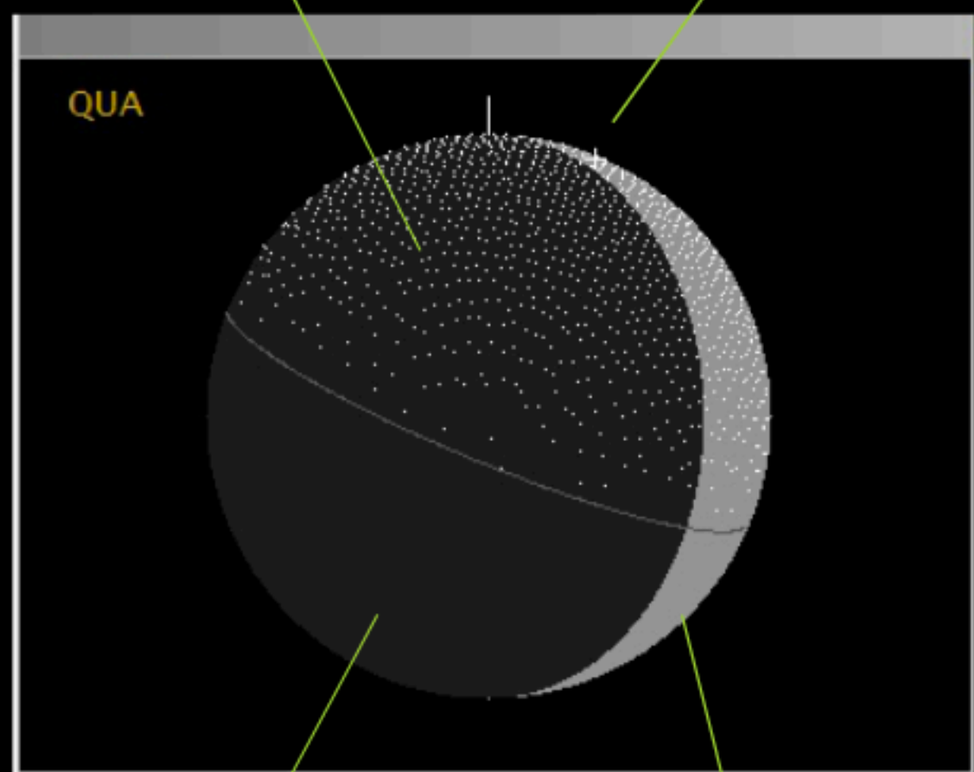
F: 2014 Quadrantids Impact Region

Option #3 = Specific Date…

01/04/2014 7:00:00

Potential Impacts

Radiant Sub-point



LunarScan Console Window

```
##################################################
########  LunarScan PREDICTION Processing  #######
##################################################

 Enter Prediction Mode:
          1 = FULL YEAR --> Files
          2 = FULL YEAR - Single Step Thru
          3 = SPECIFIC DATE - Nearest Shower
          4 = SPECIFIC DATE - All Active Showers

 ----------------------------------------------
 Selection:


 Enter desired date & UT   3/15/1998 15:00:00
01/04/2014 7:00:00
 opened log file Data\lunar_impact.log for writing
 IMO                                Arrival  Moon-Sun  Impacts  Polar
Shower                               Delay   Rise/Set   unlit   Graze
 Code      Date      Time UT        Hours     Hours    face %  Angle   ZHR
------  ----------  --------      -------   --------  -------  -----   ---
  QUA   01/04/2014  07:00:00       +0.4       2.7       38      62    120
```

Dark Face

Sun Illuminated

Encounter Geometry Info

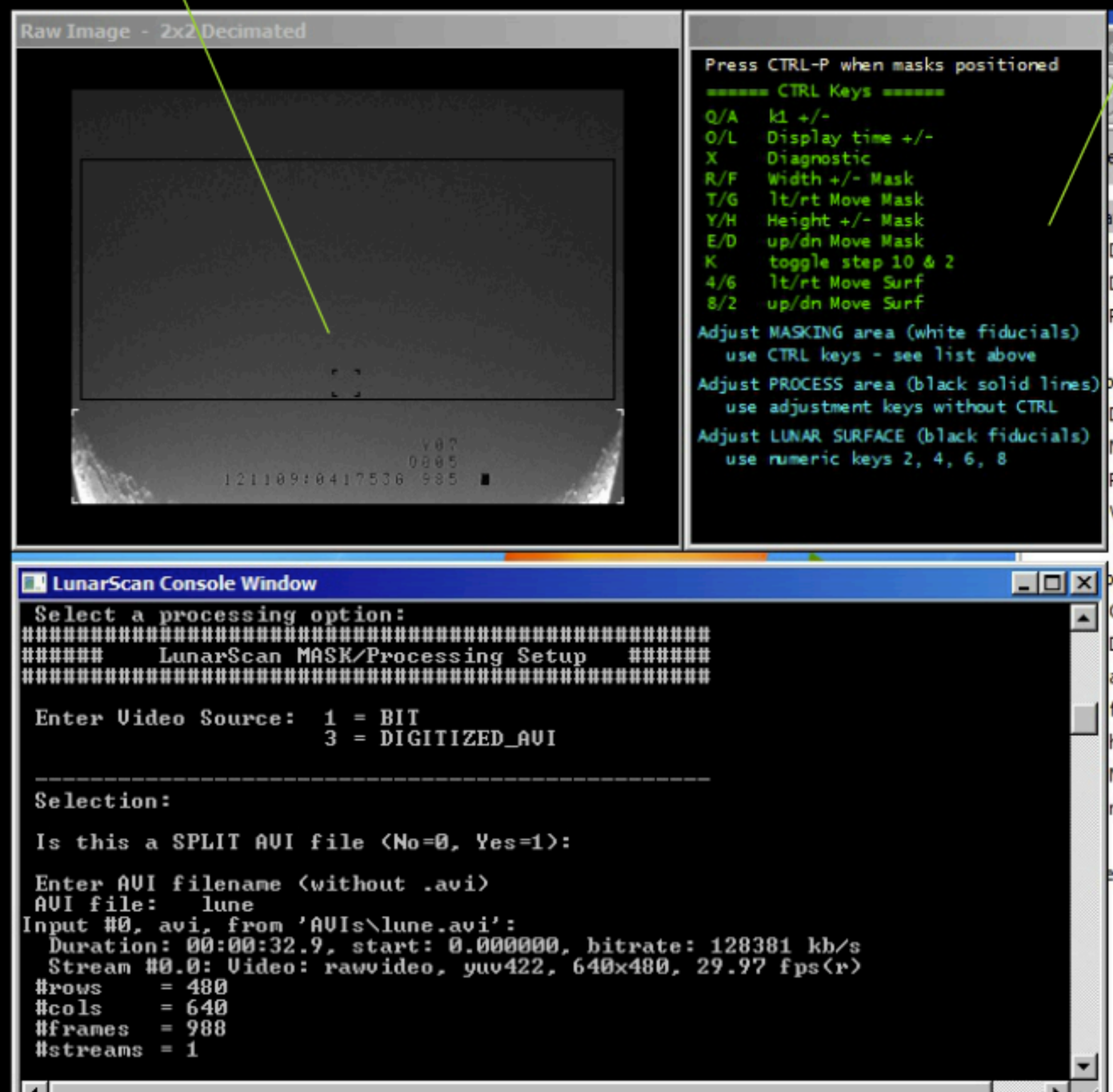
1: Define Masking / Processing / Lunar Regions

Lunar Surface

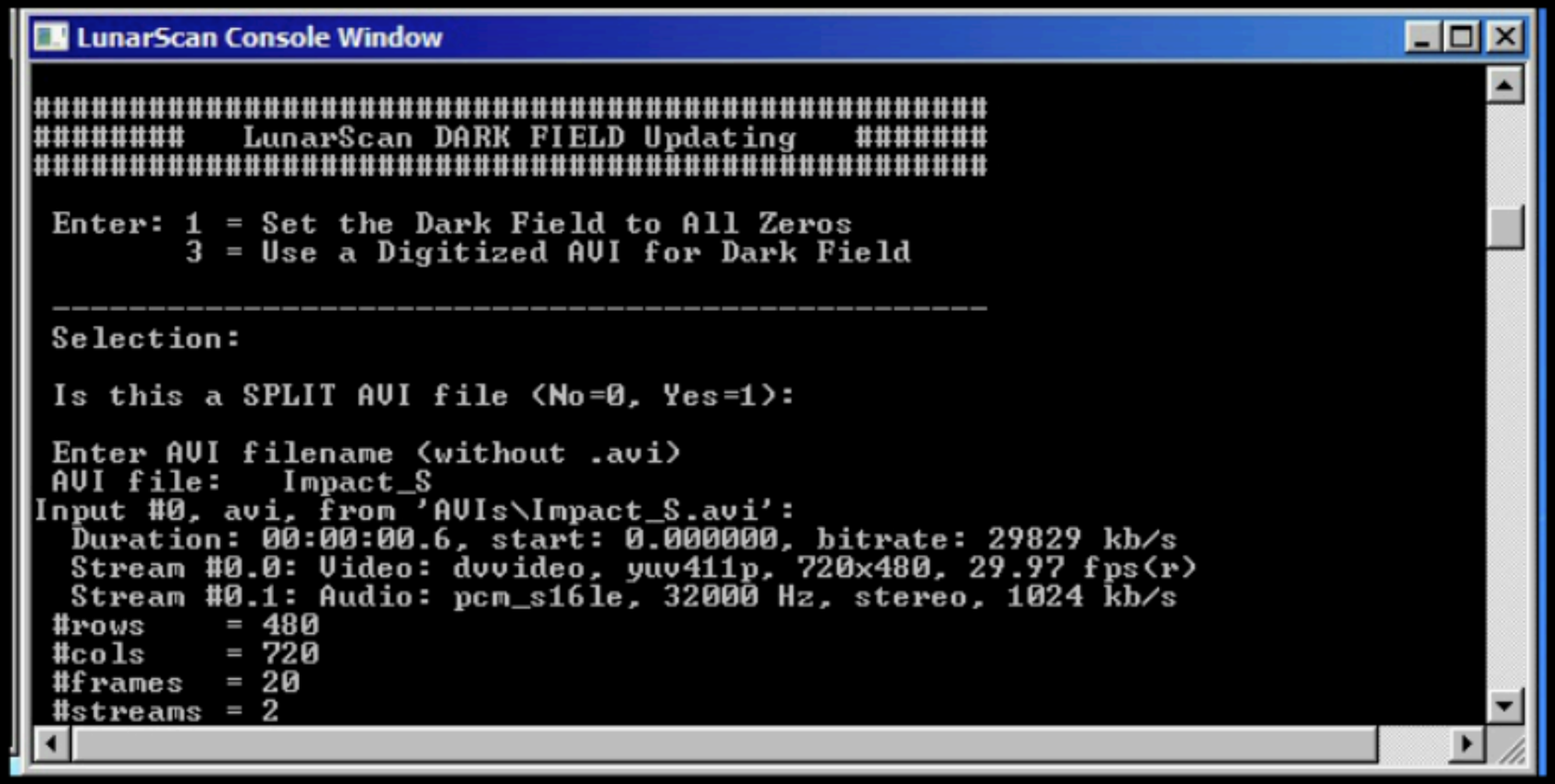
Region Adjustment Directions

Processing Rectangle Region

Masking Rectangle Region



2: Build Dark Frame



Either set to all zero or use a collected dark image AVI → avoid hot pixels !

Creates a *darkfield.dat* file

3: Scan for Impacts / Lastsettings.txt

Version = 1.500000

THRESHOLD FACTORS:

k1 -> 4 x Primary sigma factor	= 10
k1plus -> extra above k1 for doublet	= 4
Frame look back for differencing	= 1

DETECTION PROCESSING PARAMETERS:

Movie loop 1/2 band width (pixels)	= 15
Patch size (odd #pixels with max 33)	= 33

SCAN MODE DEFAULT PARAMETERS:

Mode: 1-BIT 3-AVI	= 3
Frame Proc: 0-Mean 1-Registered	= 1
Cluster: 0-Trips 1+Pixel 2+Doubles	= 2
Segment Surf: 0-No, 1-Manual, 2-Auto	= 2
Save Format 0-No, 1-Frame, 5-Mean	= 1

PROCESSING REGION PARAMETERS:

Row for the top of proc. window	= 80
Row for the bottom of proc. window	= 359
Column for the left of proc. window	= 10
Column for the right of proc. window	= 629

MASKING REGION PARAMETERS:

Row for the top of the mask	= 371
Row for the bottom of the mask	= 478
Column for the left of the mask	= 1
Column for the right of the mask	= 638

LUNAR SURFACE REGION PARAMETERS:

Row for the top of the region	= 324
Column for the left of the region	= 302
Std dev factor for minimum median	= 3.50
Std dev factor for maximum median	= 15.0

TRACKING FILTER RESPONSE COEFFICIENTS:

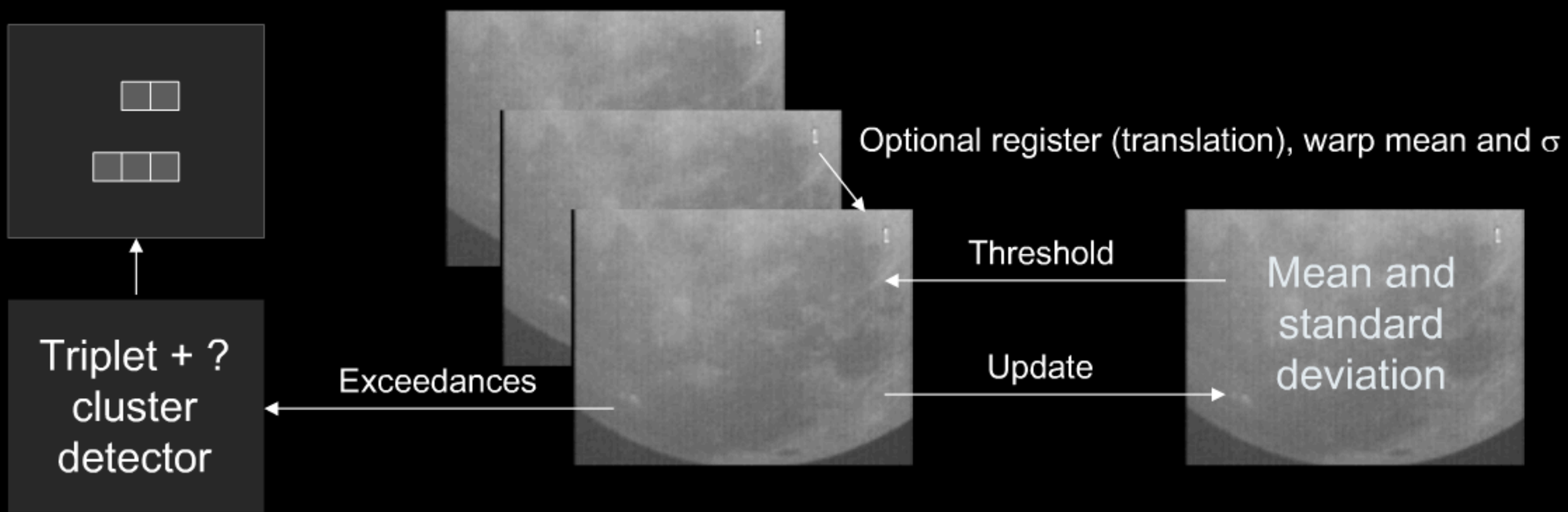
Primary coef, 2 raised to this power	= 4

FILE CONTROL PARAMETERS:

Digital Input File Directory	= AVIs\
Output File Directory	= Data\
Number saved TIFs before and after	= 5

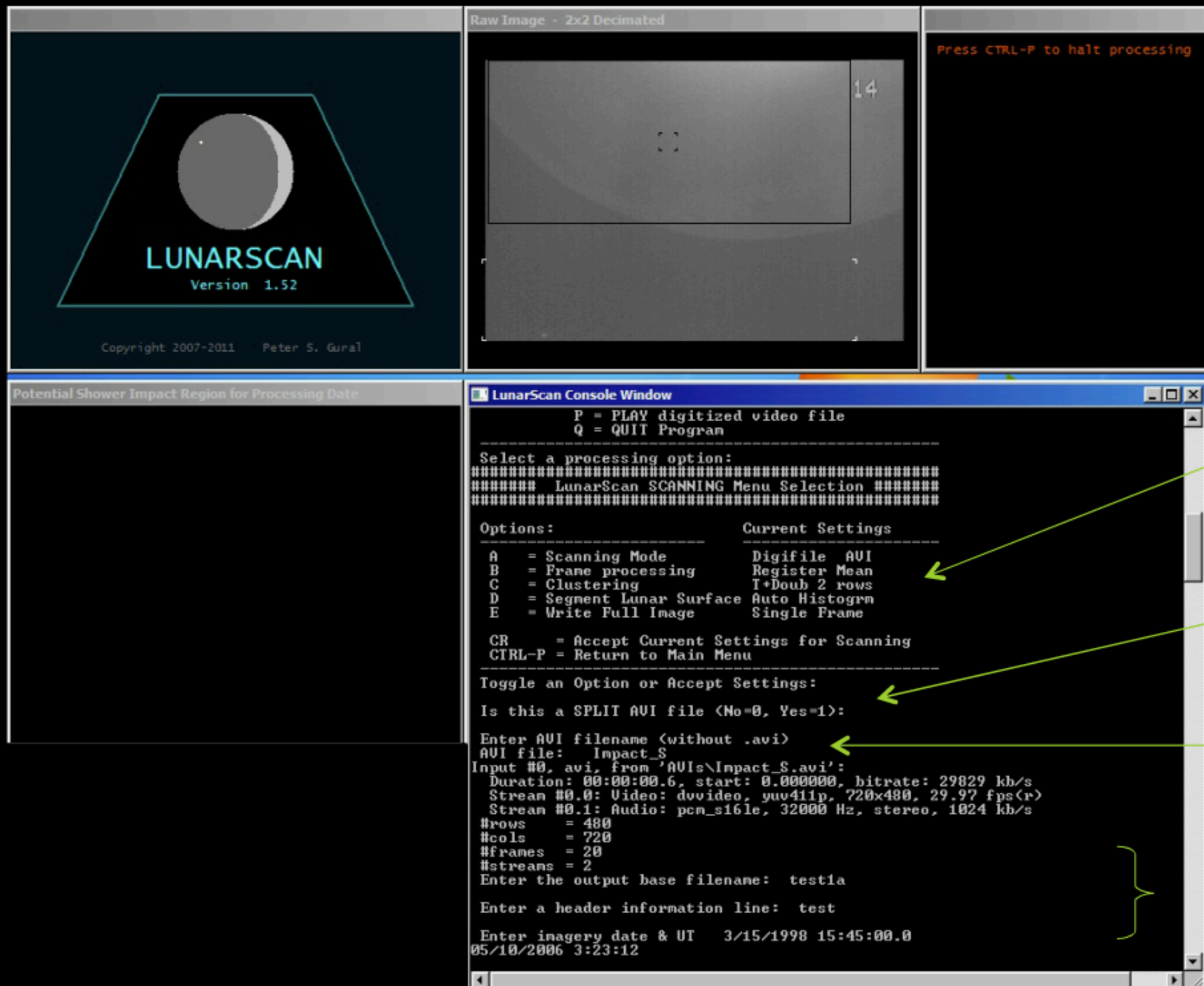
3: Scanning Detection Algorithm

- ✓ **Difference frame relative to unregistered running mean + kσ**
  - *Assumes small FOV drift and fast 1st order response filter*
- ✓ **Difference frame relative to frame-to-frame registered mean + kσ**
  - *Lower false alarm rate but much higher run time*



- **Look for horizontal triplet + singlet or doublet 2 rows above or below**

3: Scanning Display



Switchable Processing Options

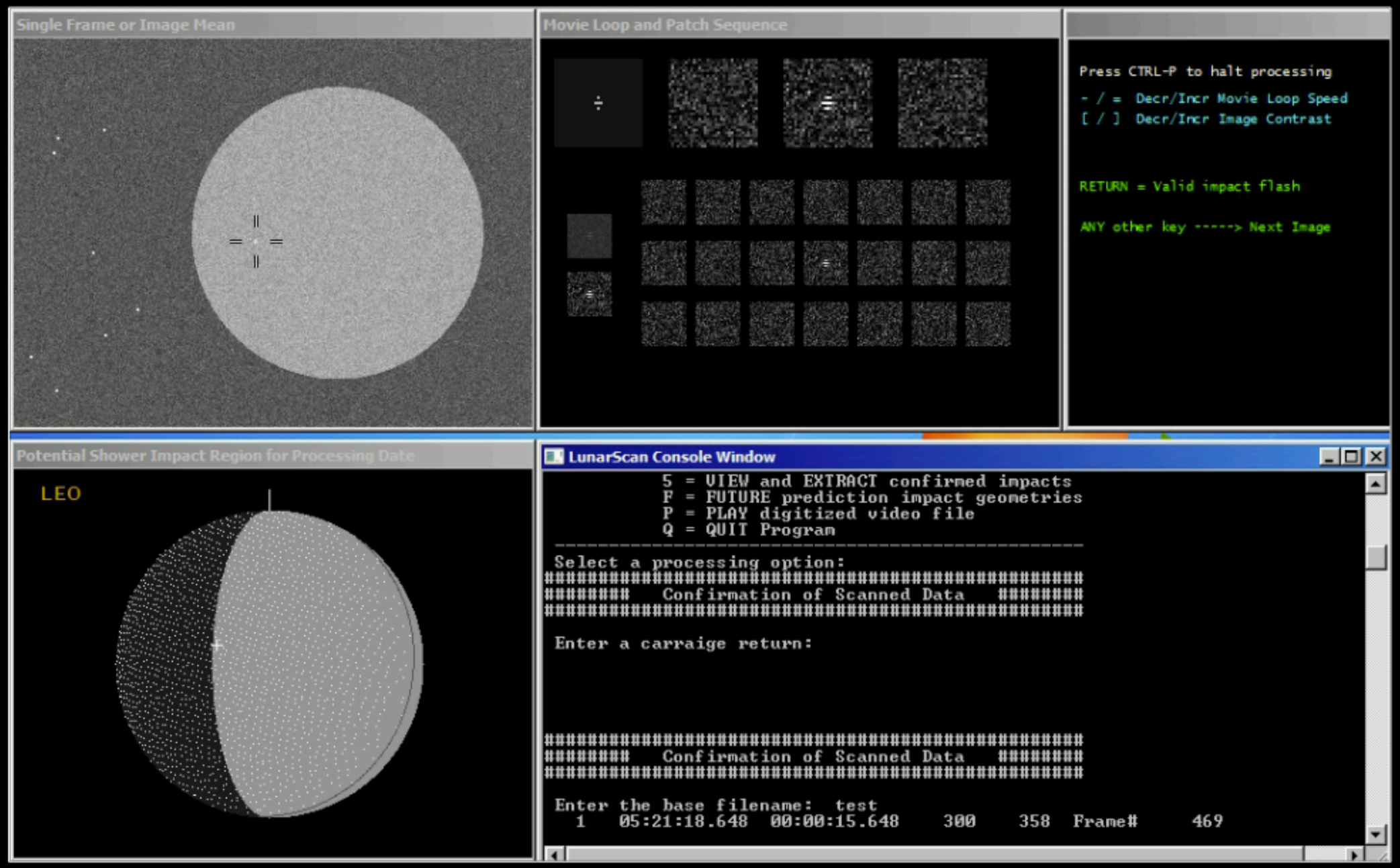
Split AVI (no longer req'd)

Enter AVI filename

Output filename
Header info
Date / Time(UT)

4: Confirmation of Impacts

BIT Simulation



Commands for:

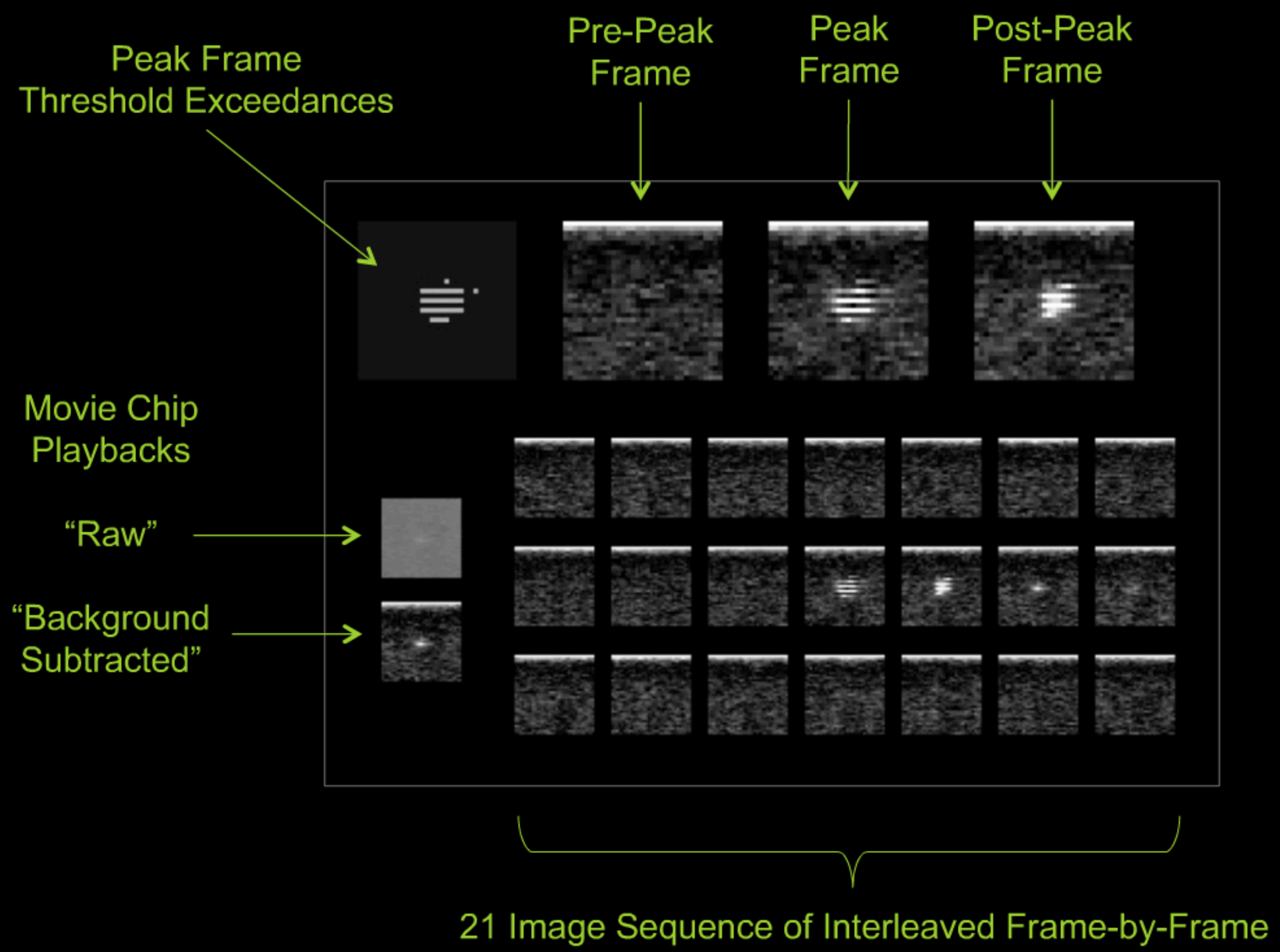
Playback speed

Contrast

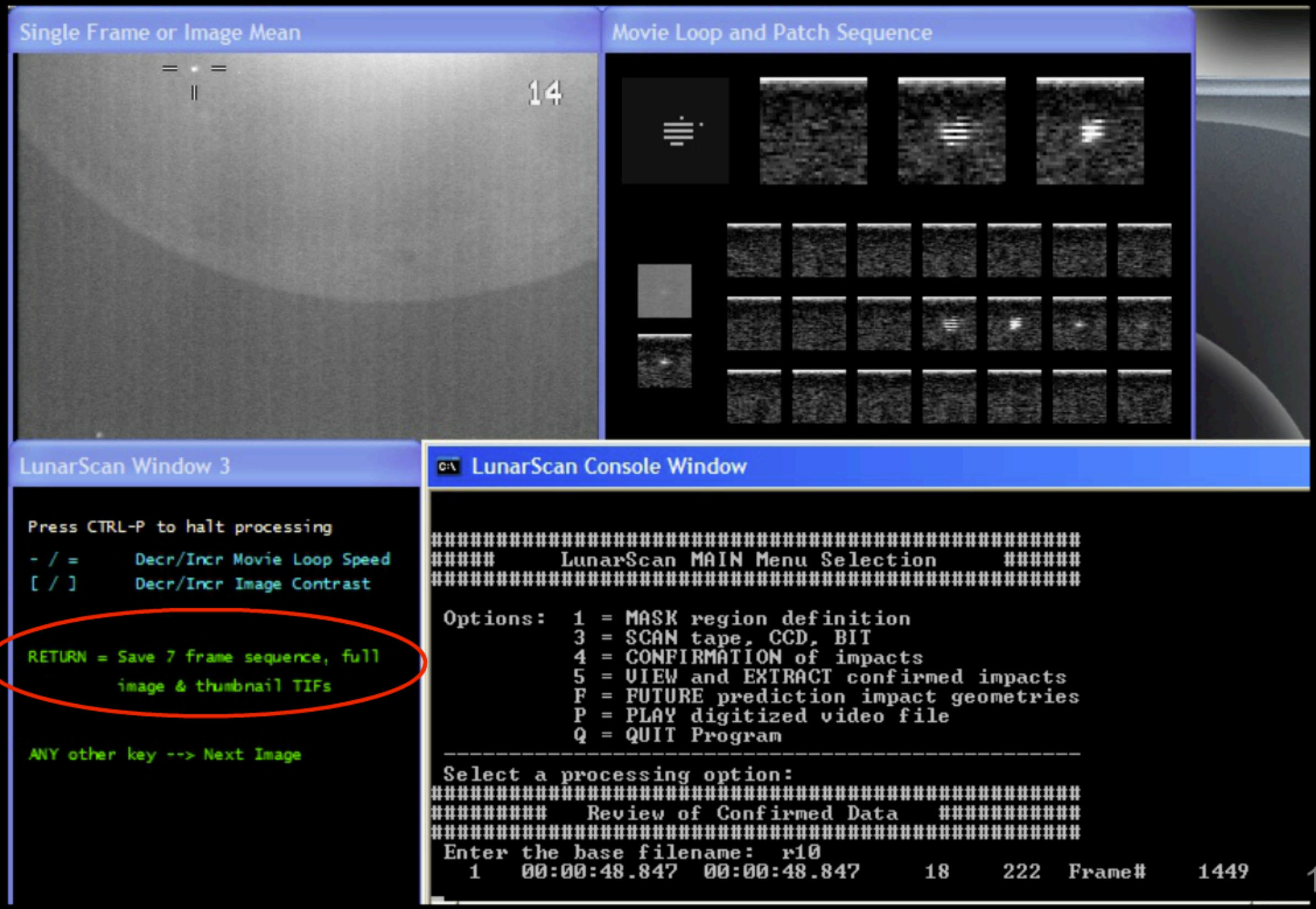
Accept / Reject

Time of Impact (UT and elapsed), row/column, frame#

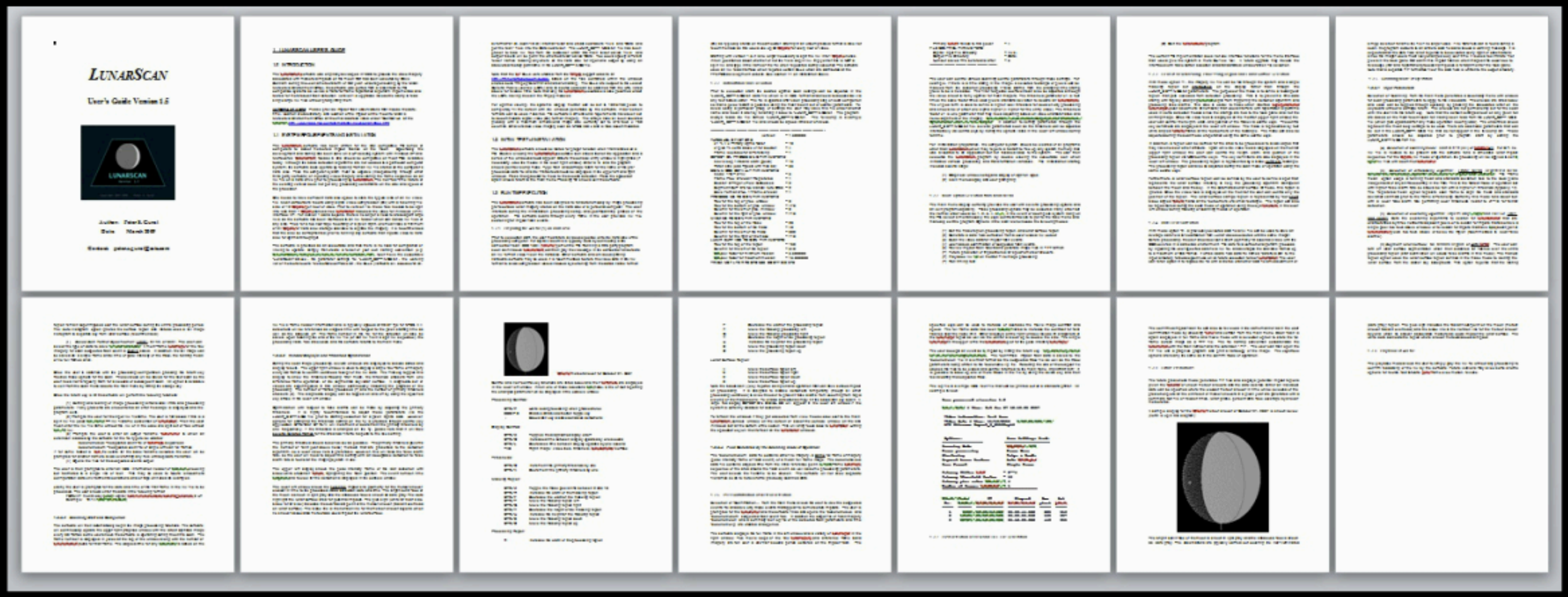
4: Confirmation Upper Right Window



5: Review and Extract Confirmed Impacts



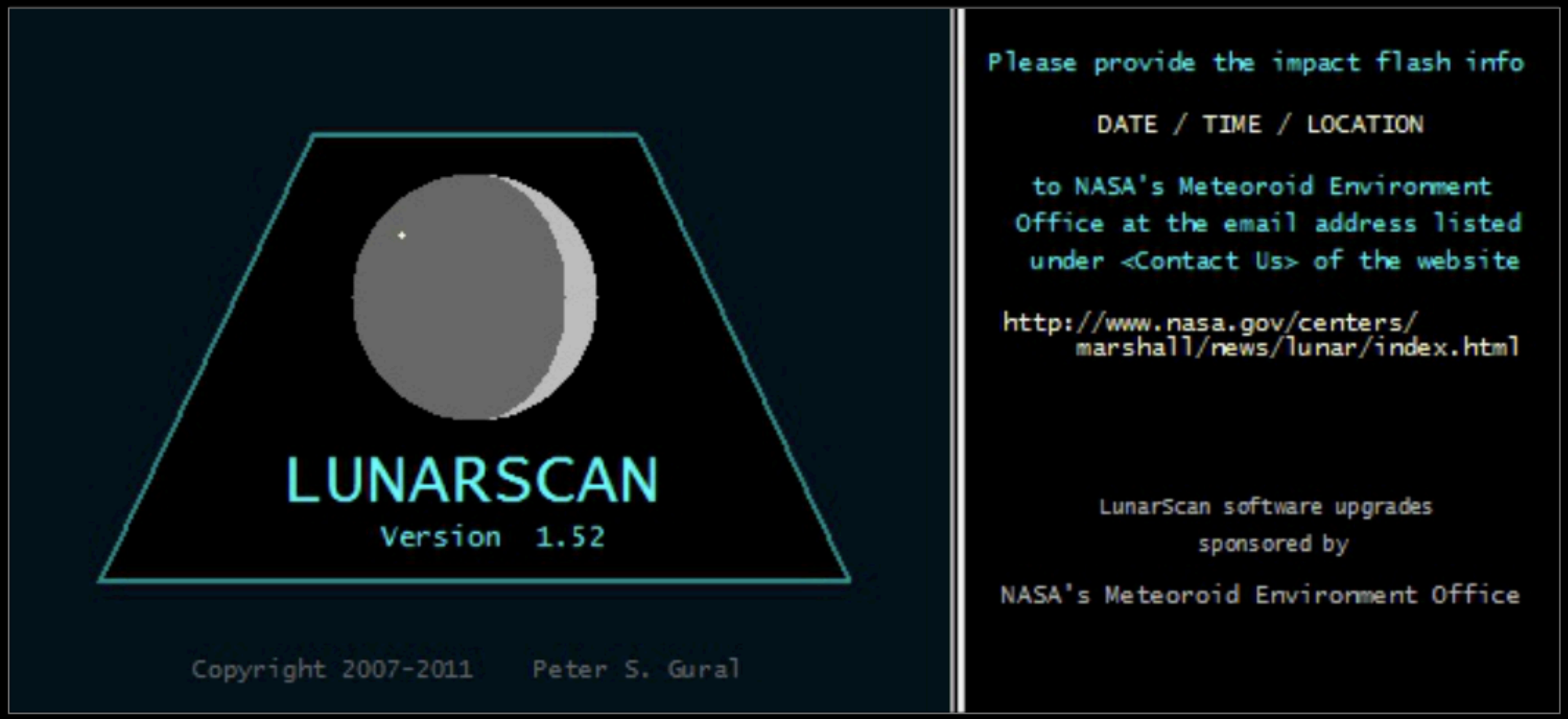
LunarScan User's Guide Available



ftp://aquarid.physics.uwo.ca/pub/gural/LunarScan1.53/

www.lunarimpacts.com

Send Results to: NASA / Marshall MEO

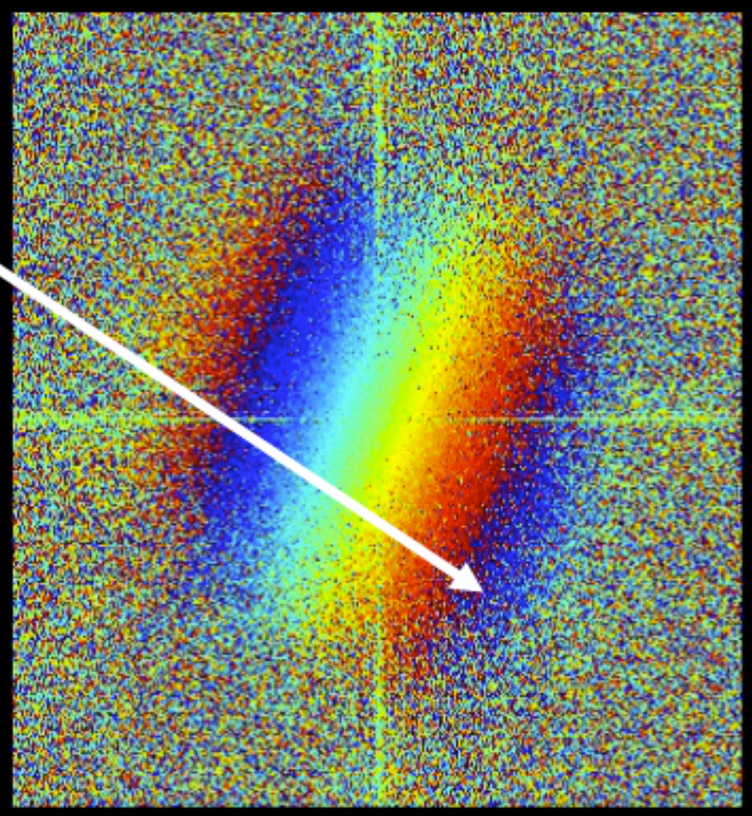


Questions ?

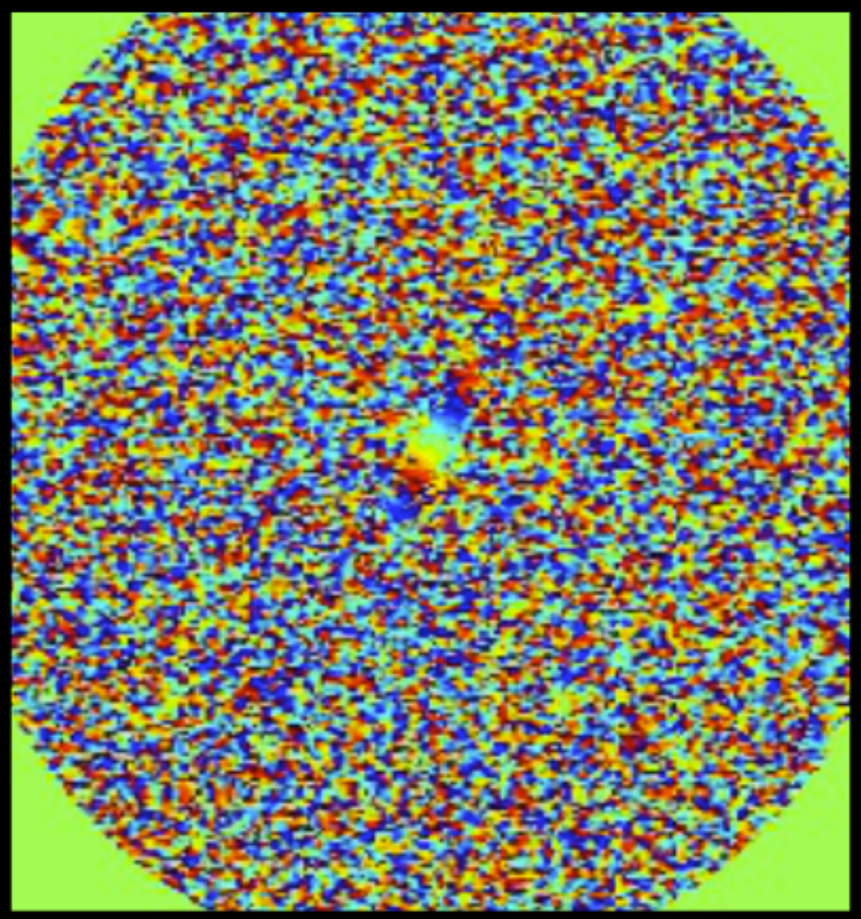
Backup Charts

PCM for Frame-to-Frame Registration

Moderately spatially aliased image



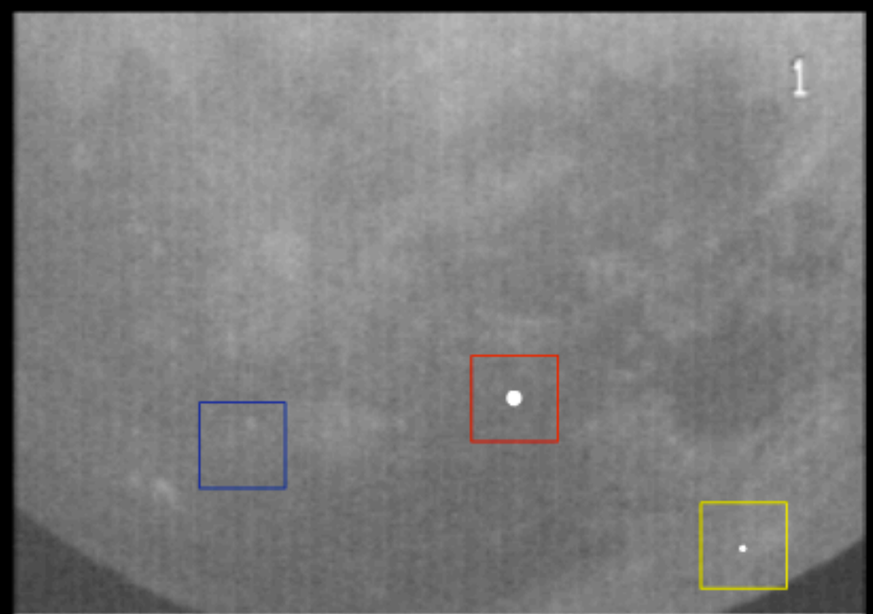
Typical lunar image pair

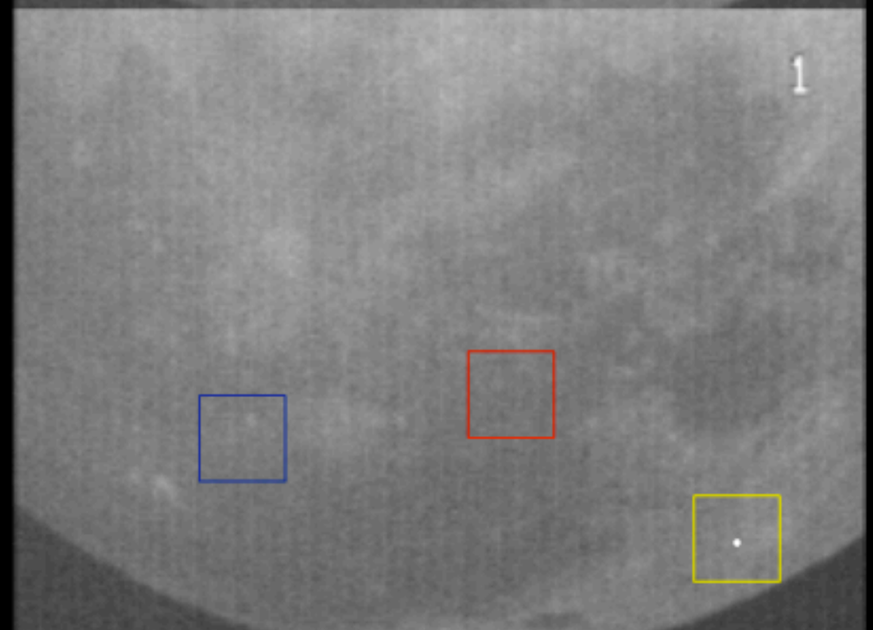


- **Phase Correlation Method**
  - *Translation in image domain → phase slope in Fourier domain*
  - *High spatial aliasing and noise in low contrast lunar images*
  - *Process central region of phase correlation matrix*
  - *Best accuracy maximizing FOV → runtime issue for 2D FFT*

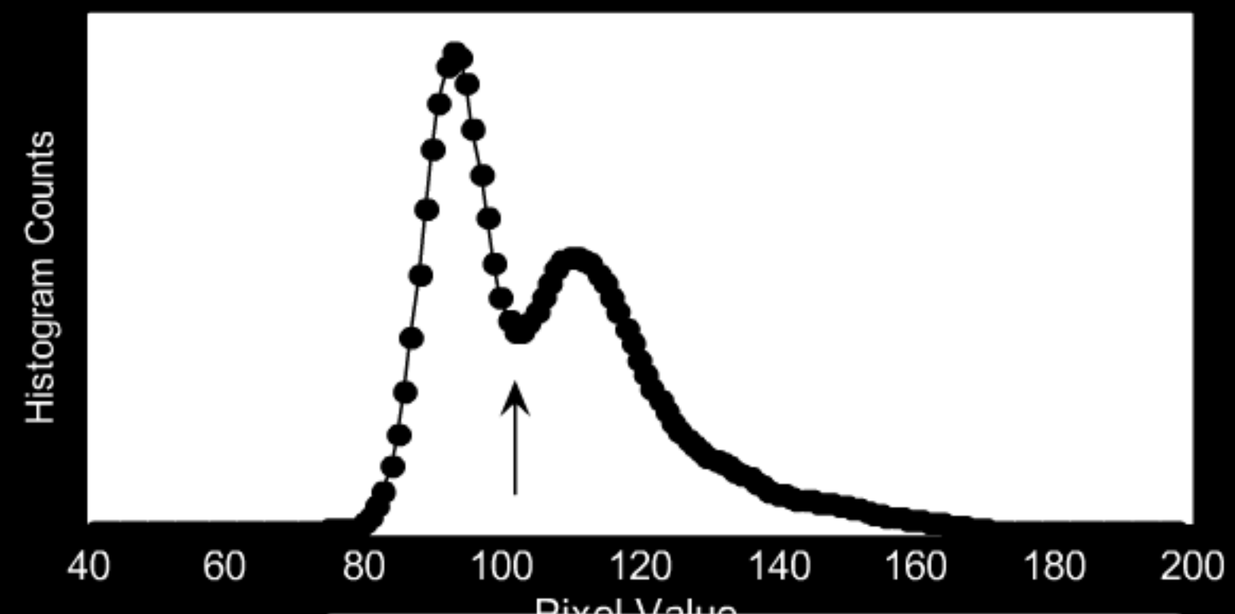
Mitigating False Alarms

- **Co-register local patch from 2 frames around potential detection**
  - *Use spatial cross correlation*
  - *Good for unregistered frames*

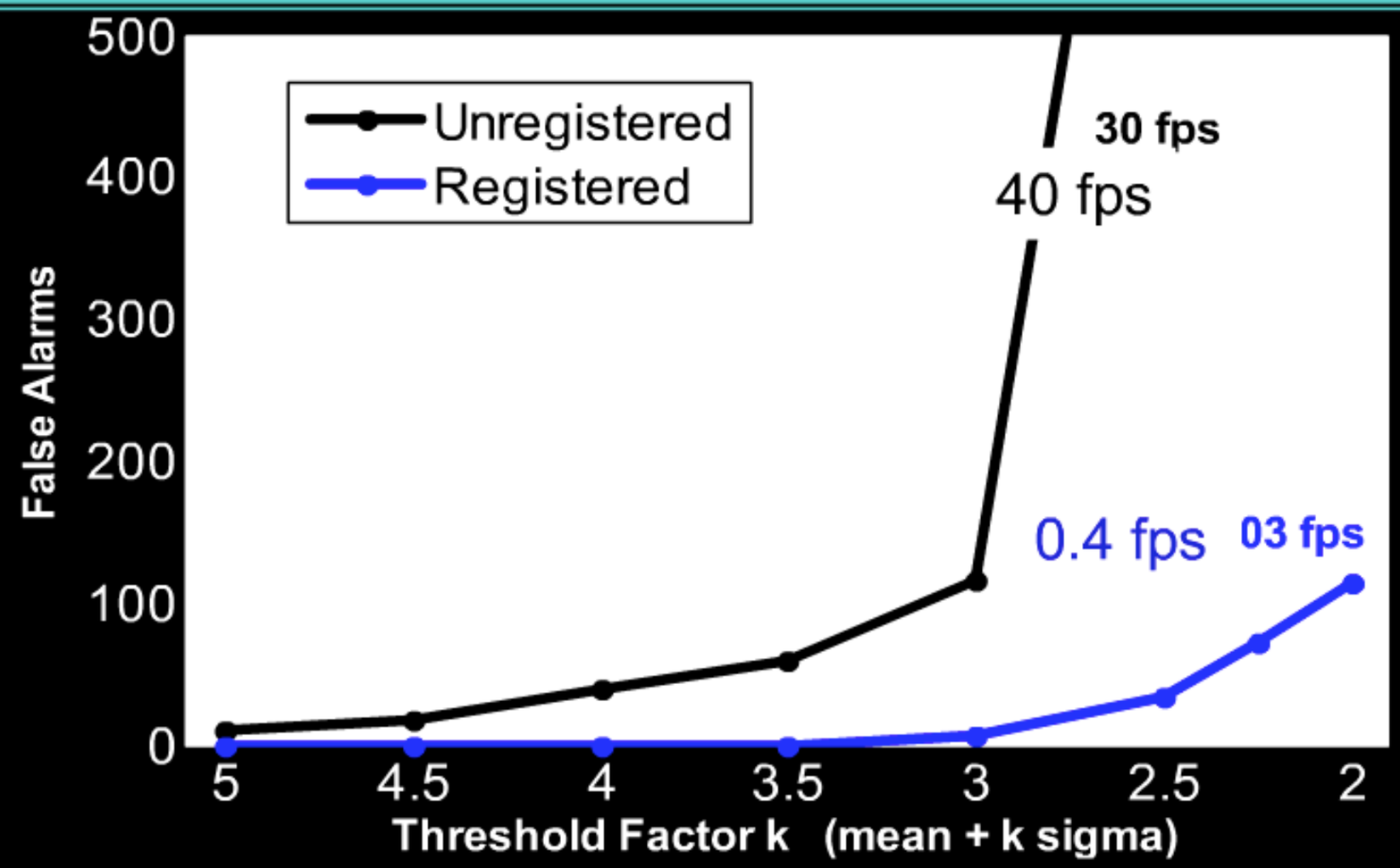


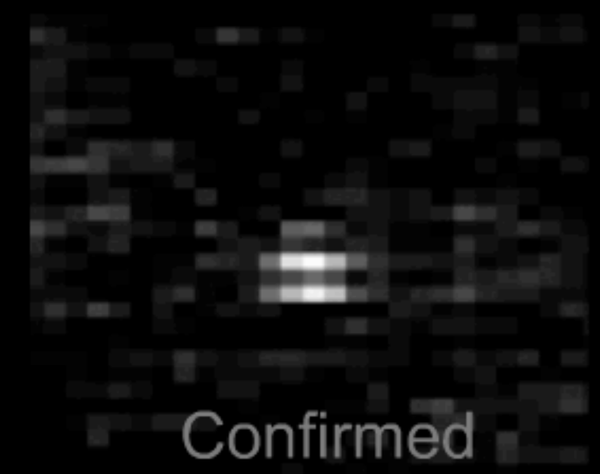


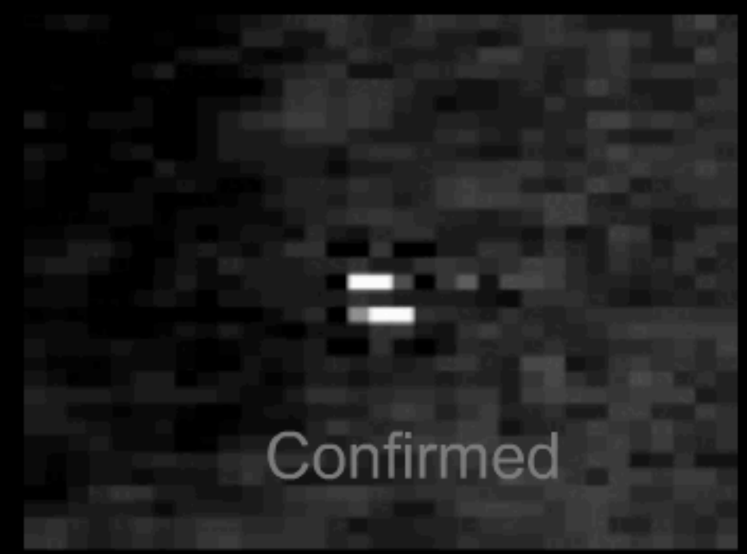
- **Segment lunar surface and sky**
  - *User defined patch on surface*
  - *Automated via histogram processing*
  - *<u>Fast</u> median filter to exclude stars*

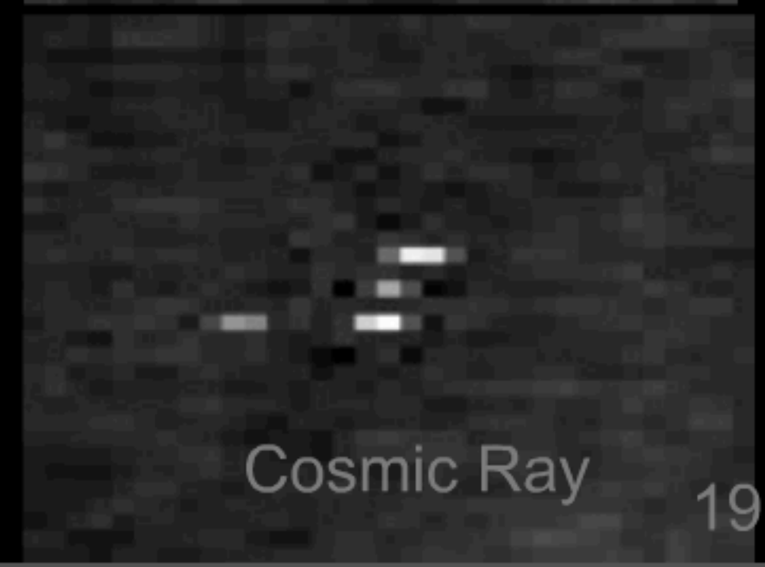


Performance









- **LunarScan Enhancements**
  - *FFTW for optimal Fourier transform speed*
  - *Difference frame processing*
  - *Code optimization, faster median filtering*
  - *Large AVI file reader (>2 Gbytes)*