Session 5A: Multicopters for Inspection

HOIS Guidance for UAV based external remote visual inspection

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Engineering, Safety & Risk

Introduction to HOIS Joint Industry Project (JIP)

HOIS is a major well established (>35 years) JIP on good practice for NDT/NDE in the energy industry

Nearly 40 Members comprising:

- Energy asset owners/operators
- NDT service companies
- NDT equipment vendors
- NDT notified bodies
- A regulatory authority (UK HSE)
- The OGTC

Annual budget of ~£800,000

Global representation: Americas, UK, Europe, Middle East, Australasia

Managed by ESR Technology

Motivation: Need for external remote visual inspection (RVI) guidelines

Visual inspection probably the oldest NDT method

Unmanned aerial vehicles (UAV) for external RVI recent and growing area:

- Information on the **external** condition of piping, vessels, tanks etc
- For engineering assessments of condition

HOIS members reported substantial variations in the quality of the digital images that comprise the final deliverables

External RVI not covered in any detail by International Standards. Brief reference only in

- ASME V Article 9 which states that RVI needs to be demonstrated to an equivalent resolution to CVI/DVI

No evidence of usage of this standard in current UAV based RVI

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Aims and scope of HOIS UAV project

Focus on quality of arising RVI imagery from external inspection

Not addressing UAV pilot certification, nor site deployment/operational aspects

- Covered by others elsewhere
- e.g. Unmanned Aircraft Systems (UAS) Operations Management Standards and Guidelines, Issue 1, Oil & Gas UK January 2017.

Emphasis on stills not videos

Visible spectrum only (not IR)

Aim was to develop guidance for the energy industry on minimum quality of UAV imagery needed for different applications

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Challenges

Visual Inspection traditionally performed by a human inspector

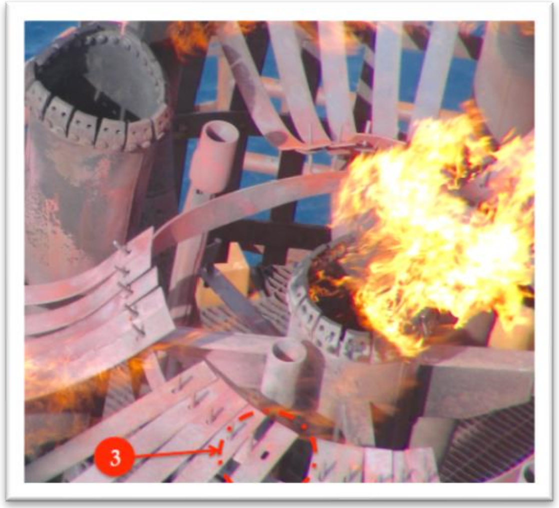
Usage of UAVs that generate digital images as the end deliverable relatively new

Current visual inspection standards lack quantitative measures of image quality

- Unlike other forms of NDT, such as radiography and ultrasonics

Wide range of UAV applications

- Potentially different quality standards for each one
- “One size will not fit all”



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HOIS members survey: Application areas & quality measures

Obtained feedback from members to establish which UAV based RVI applications have highest priority for guidance on image quality:

- Close/direct visual inspection (CVI/DVI)
- Assessment of coating condition to ISO 4628
- Flare-tip inspection

Quality measures emerging from survey were:

- Spatial resolution – discussed in this paper
- Noise level in images (signal to noise ratio) - see HOIS guidance due to limited time

Similar to digital radiography standards (e.g. ISO 17636:2 & ISO 20769)

Varying quality requirements for different applications

- Focus of this paper on close visual inspection - CVI

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Spatial resolution

An important measure of image quality in RVI

Needs to be specified on the object being inspected or “target”

NOT in terms of number of pixels in camera sensor

Best measured using line pairs per mm

Can also use reciprocal mm/lp – similar to radiographic unsharpness

Key issues

- What resolution is needed in UAV based RVI
- How can this resolution be achieved?

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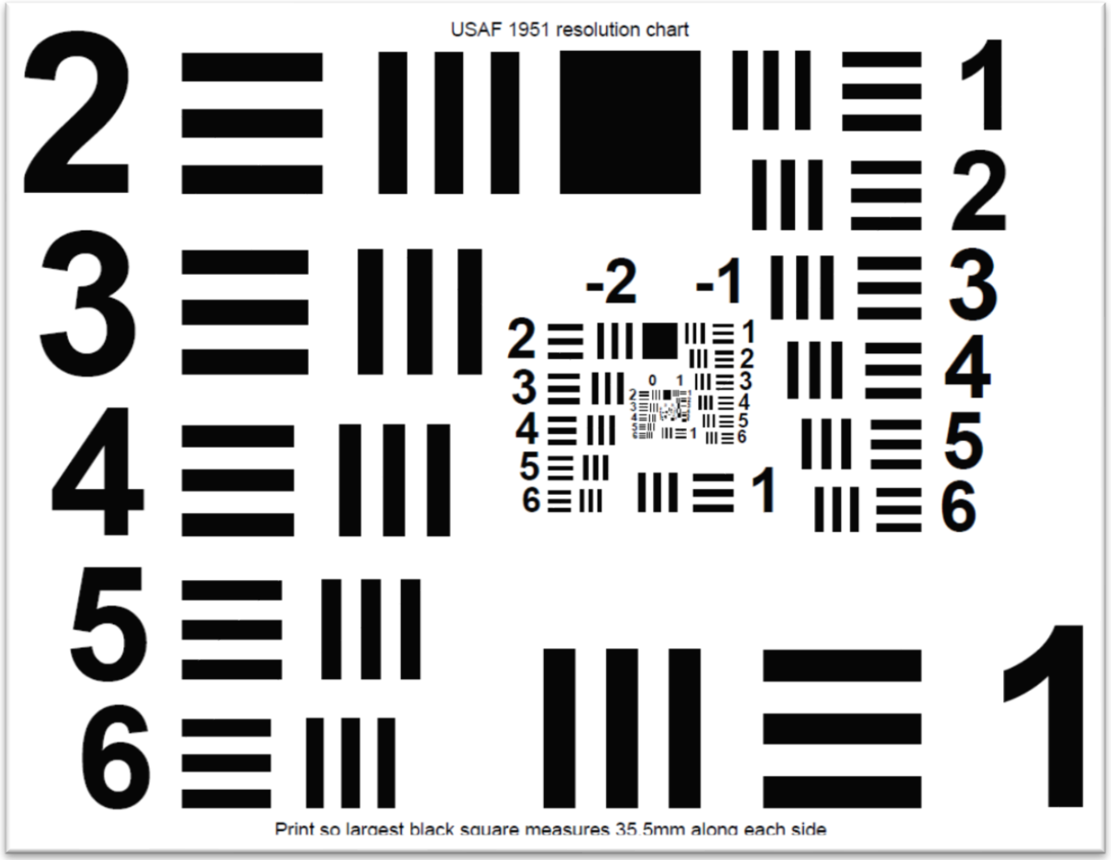
Measure resolution
Use a standard chart: USAF 1951

Different bar patterns arranged in groups and elements within each group

Referenced in BS EN 13927:2003

Is widely used for assessing resolution of various optical systems

Works well in practice



$$\text{Resolution (lp/mm)} = 2^{\text{Group}+(\text{element}-1)/6}$$

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Resolution needed to match Close Visual Inspection (CVI)

ASME V Article 9, and BS EN 17637 state:

- Surface being inspected should be no further than 600mm from the human eye
- Inspector’s eyesight must meet a specified acuity level

We placed USAF 1951 test chart ~600mm from various human eyes that all passed the acuity test

Consensus was that resolution just discernible on the chart was ~3 line pairs/mm

Note: requirement in these standards to be able to discern a fine line 1/32 in (0.8mm) in width is NOT a measure of spatial resolution.

- Two closely separated lines would be needed for that

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What is needed to achieve required CVI spatial resolution using a UAV?

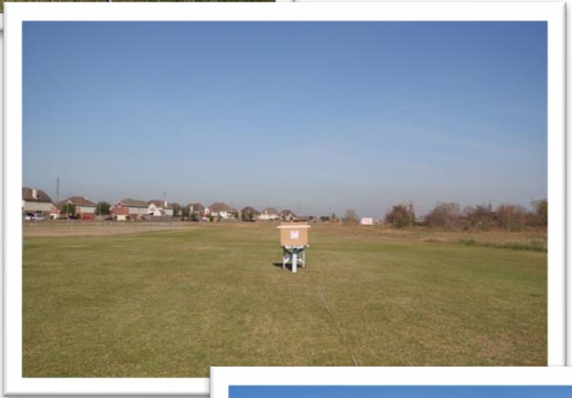
Variables which affect spatial resolution:

- Distance from target
- Lens focal length
- Sensor size
- Number of pixels in sensor
- Quality of optics and camera
- Camera shake. Out of focus. Depth of field etc

But, which are most important and how can they be related?

HOIS members USAF 1951 trials

Asked HOIS members to perform trials using airborne UAVs to image USAF 1951 charts at different distances



Instructions to participants:

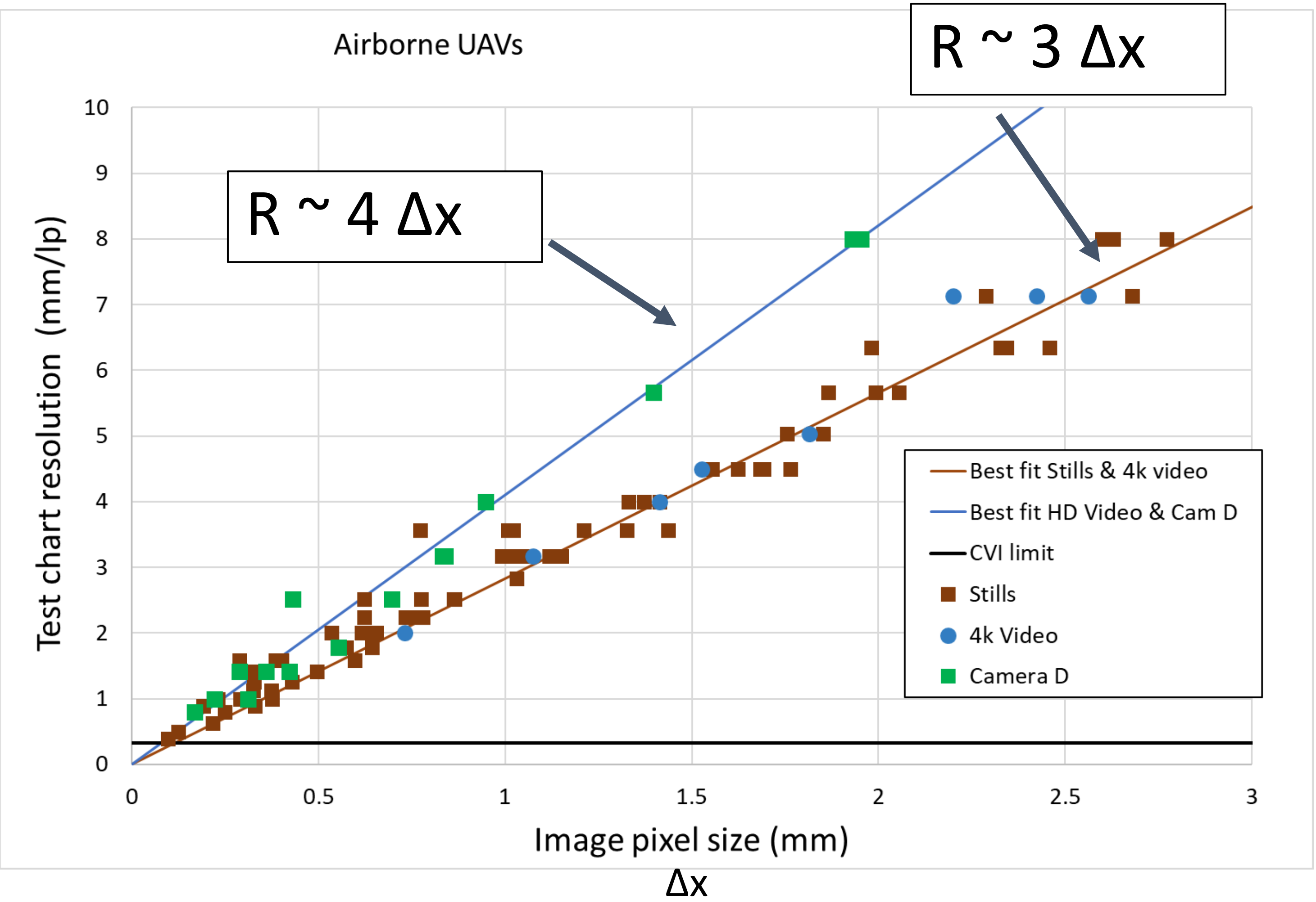
- Use imaging devices normally deployed for RVI
- Start at min distance normally used for RVI
- Provide images (& videos) for analysis with info on distances to target, focal length etc

Results from trials: resolution as a function of pixel size on the USAF 1951 chart

Key variable is pixel size, Δx, on the chart.

Two linear trendlines with different gradients for different imaging devices used:

- Most devices had R ~ 3 Δx
- A few were slightly poorer with R ~ 4 Δx
- Unclear why



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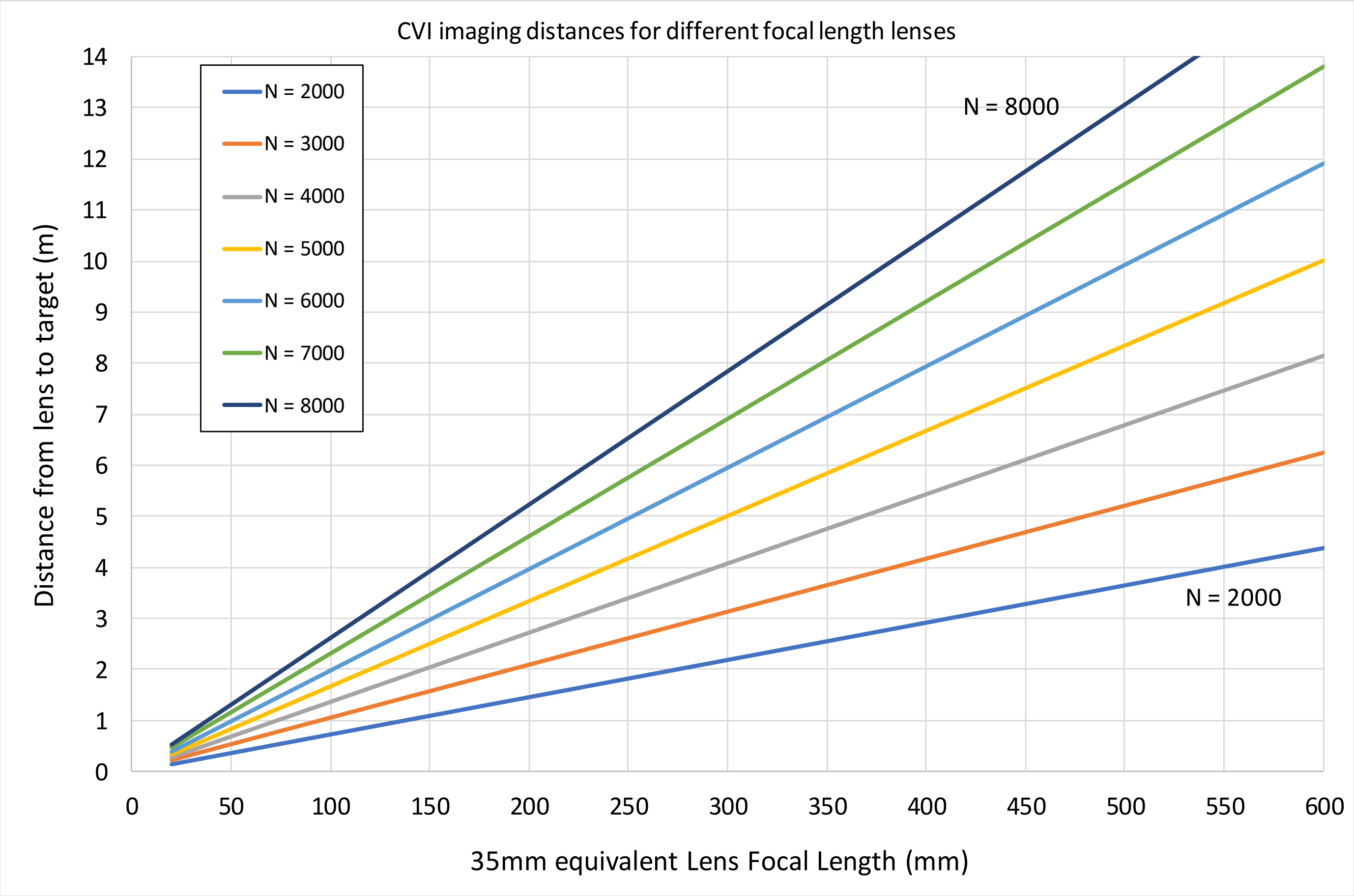
Distances from UAV to target needed for CVI resolution

Can calculate approx. distance to target needed to achieve CVI resolution, given:

- Lens focal length
- Number of pixels in image, N

Assumes imaging system has “standard” relationship between pixel size and resolution
$R \sim 3\,\Delta x$

Smaller distances needed if
$R \sim 5\,\Delta x$



Verification of spatial resolution on target

How to verify that the required resolution has been achieved:

- Include a resolution chart in the image – practical issues?

OR

- Determine image pixel size on target, Δx, given a feature of known size in the image, and infer resolution from that
- View image at 1:1 magnification and check for any lack of sharpness due to motion blur, out of focus etc

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HOIS Guidance for UAV based RVI

CONTENTS:

1. INTRODUCTION
2. GLOSSARY OF TERMS AND ABBREVIATIONS
3. RELEVANT STANDARDS
4. SCOPE
5. IMAGE QUALITY RECOMMENDATIONS
6. GENERAL GUIDANCE FOR UAV BASED RVI

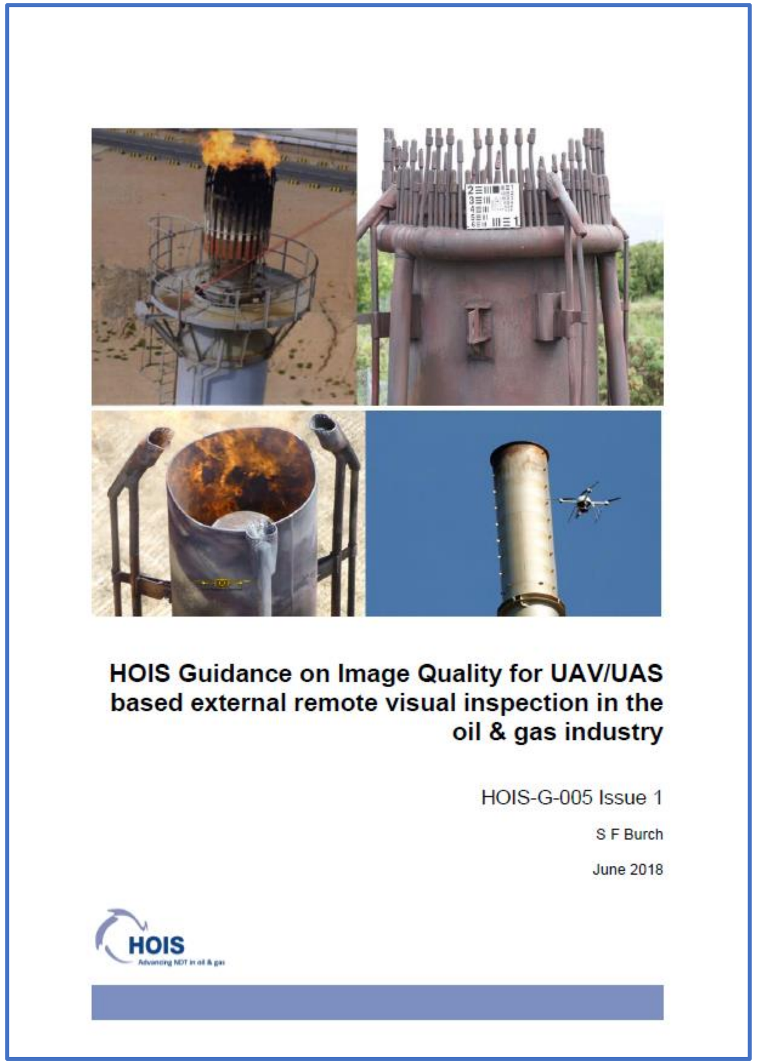
Appendices

Now publicly available for download from the BINDT store.
https://www.bindt.org/shopbindt/hois-documents/

Since 2018 publication:

ASME V Article 9 revised to include reference to resolution charts (e.g. USAF 1951)

HOIS guidance being referenced in some industry tenders


HOIS Guidance on Image Quality for UAV/UAS based external remote visual inspection in the oil & gas industry

HOIS-G-005 Issue 1

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Conclusions

Recently increased usage of unmanned aerial vehicles (UAV) for external RVI:

- To obtain information on the **external** condition of piping, vessels, tanks and structures
- So that engineering assessments can be made of their condition

Lack of guidance had led to substantial variations in the quality of the digital images that comprise the end product of the inspection

HOIS project has examined key image quality measures by means of members' trials.

Developed guidance that seeks to achieve more standardisation in quality of the end deliverables (i.e. images)

A key parameter is **spatial resolution achieved on the object**. Also SNR important.

Acknowledgements

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