NTIA Memorandum 20-545

ITS4S4: A Video Quality Study of Camera Pans

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technical memorandum

U.S. DEPARTMENT OF COMMERCE • National Telecommunications and Information Administration

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DISCLAIMER

Certain products, technologies, and corporations are mentioned in this report to describe the experiment design. The mention of such entities should not be construed as any endorsement, approval, recommendation, prediction of success, or that they are in any way superior to or more noteworthy than similar entities that were not mentioned.

PREFACE

This memorandum is part of a series of NTIA Technical Memorandums. Each publication describes a subjective experiment that is named in series and distributed freely on the Consumer Digital Video Library (CDVL, www.cdvl.org) for research and development purposes. These experiments provide training data for no-reference (NR) metrics that focus on consumer camera applications. The reader is expected to have some knowledge of subjective experiments. A tutorial on this subject can be found in "Video Quality Assessment: Subjective testing of entertainment scenes," by Margaret H. Pinson, Lucjan Janowski, and Zdzislaw Papir, published in *IEEE Signal Processing Magazine*, January 2015.

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GLOSSARY OF TERMS

Clip	The base unit of this subjective test: a 4 second long video recording
FPS	Frames per second or fields per second
NR	No-reference
NR Feature	Intermediate calculations while calculating NR Metrics (e.g., local estimate of blurring or noise)
NR Metric	A metric that predicts the quality of an image or video using only the image or video itself (i.e., pixels) without referencing the bit-streams, coding parameters, or a higher quality version of the image or video
NR Parameter	An NR metrics that measure the quality response of a single impairment, used to provide root cause analysis
RCA	Root Cause Analysis
Root Cause Analysis	NR metric analyses that divide the overall quality into multiple factors, to explain why the quality dropped
Original Resolution	The resolution as recorded by the camera
Viewed Resolution	The resolution presented to the subjects (1920 × 1080)

ITS4S4: A VIDEO QUALITY STUDY OF CAMERA PANS

Margaret H. Pinson[1], Samuel Elting[2]

This technical memorandum provides technical details for the video quality subjective experiment **its4s4**. This experiment includes 196 videos, each 4 seconds in duration, depicting camera pans at different speeds. Other impairments are avoided where possible. This experiment implements an unrepeated scene design, so each 4 second video contains unique content. The **its4s4** dataset provides training data for no-reference video quality metrics that predict quality impairments associated with camera pan speed. The dataset is freely available for research and development purposes.

Keywords: Camera pan, no-reference metric, public safety, subjective testing, video quality

1. INTRODUCTION

Subjective video quality experiment **its4s4** is the fourth experiment conducted in a continuing series of experiments. All four experiments were designed to provide insights into video quality metrics that evaluate camera capture. Most of the videos in the **its4s4** dataset represent common scenarios encountered by first responders. The video clips characterize camera pans at different speeds, from no camera movement to extremely fast. The videos avoid other impairments where possible. Half of the videos contain simulated pans; the other half contain camera pans from a variety of cameras and videographers.

Our objectives are to enable (1) intelligent cameras that help first responders to record videos and photographs that satisfy their needs, and (2) intelligent networks that take video quality into consideration (e.g., to optimize the use of network transmission resources). To achieve these objectives, technical innovations are required, including the development of a metric that can analyze the quality of video in real-time, using only the video sequence as an input. Referred to as a no-reference (NR) metric, this type of metric has proven to be a very challenging development problem. Experiment **its4s4**, like the other experiments in this series, provides training data for NR metrics.

Our prior three experiments in this series were **its4s** [1], **its4s2** [2], and **its4s3** [3]. Experiment **its4s** established an experiment design for training NR metrics, using unrepeated scenes. The concept of an unrepeated scene design is that each photograph or video recording is included only once to maximize subject matter variability. The photographs in experiment **its4s2** depict a wide variety of camera capture impairments (e.g., lens flare, aspect ratio, amateur photography). The video clips in experiment **its4s3** depict camera capture issues associated with first responder

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tasks. These impairments emphasize the difficult environments in which first responders operate (e.g., time limitations, inadequate lighting, inclement weather, amateur videographers). Two of the **its4s3** scenarios are an incident commander remotely monitoring a prison riot response in real time, and a detective filming a crime scene. Experiment **its4s3** was conducted at the 2018 Public Safety Communications Research (PSCR) Public Safety Broadband Stakeholder Meeting.

The remainder of this report provides a detailed description of the **its4s4** experiment. The video clips and ratings will be made available in the near future on the Consumer Digital Video Library (CDVL, www.cdvl.org). This dataset is available freely for research and development purposes, as per the May 09, 2013 Executive Order, "Making Open and Machine Readable the New Default for Government Information." [4]

2. DATASET DESCRIPTION

An improved understanding of how people perceive video quality would allow cameras to produce higher quality images and videos. One parameter that impacts video quality is the speed at which the camera sweeps across a view, which is known as pan speed. Knowledge of the relationship between pan speed and video quality could improve the accuracy of an NR metric.

From 2017 to 2019, the Video Quality Experts Group (VQEG) No Reference Metric (NORM) group discussed industry requirements for NR video quality metrics. Industry participants determined that a prediction of the overall quality was inadequate. NR metrics must provide root cause analysis (RCA) that measures the quality response of a single impairment and explain why the quality dropped. We will refer to these as *NR parameters*.

Experiment **its4s4** explores a method for training NR parameters. We will assume that NR parameters are combined into an NR metric (to provide an overall quality estimate) and reported separately (to provide RCA). The training method is as follows:

- Create a dataset of subjectively rated media that depicts a specific impairment and omits other impairments, to the extent possible
- Train an NR parameter on the dataset
- Verify the performance of the NR parameter on datasets that, like **its4s2** and **its4s3**, contain a wide range of impairments
- Add the new NR parameter to an NR metric, to understand the accuracy improvement obtained from explaining this new impairment

This report addresses only the first step: creating a dataset limited as much as possible to a single impairment.

Experiment **its4s4** contains camera pans and simulated pans. The camera pans were edited from footage commissioned by ITS over the previous decade. Some of this footage was produced by professional videographers who were asked to simulate the type of footage that first responders create and use during their jobs. Simulated pans were created by panning over images obtained from Flickr®. Some of these images were panorama photographs from **its4s2**; and some of the camera pans were included in experiment **its4s3**. The **its4s2** and **its4s3** file names were retained, so that the quality ratings of the original images and simulated pans could be compared.

To focus **its4s4** exclusively on camera pans, we limit stimulus selection. Zooms and camera jiggle were minimized, because measuring and analyzing those motions will require more complex algorithms. In-frame motion was minimized, to avoid the confounding factor of objects and background moving at different speeds. Camera impairments (e.g., blurring, noise, lens distortion) were avoided as much as possible, so that the only varying parameter was the pan speed of the video. While this ideal was impossible to achieve, the frequency and magnitude of other impairments is at least reduced.

Experiment **its4s4** also omits scenes with complex motion. Consider for example a camera that is locked down on a tripod. One person is walking to the left, and another person is walking to the right. If the screen is split roughly evenly between the background and each person, then it will be difficult to determine the overall camera motion (e.g., no motion, left pan, right pan).

Pan speed was measured as the distance across the screen the image moves per second (IPS). For example, if an image moves at 0.15 IPS, then one point on the image will travel across 15% of the screen in one second. This is more practically calculated as the number of pixels the image moves in one direction per frame. Since the frame rate of the video is known, the overall IPS value can be calculated as

$$IPS = Frame\ Rate \frac{\Delta pixels}{Total\ Pixels}$$

where *Frame Rate* is the number of frame updates per second, *Total Pixels* is the number of pixels in the direction of the motion, and Δ*pixels* is the distance in pixels an object moves between one frame and the next.

The **its4s4** videos were edited to be 1920 × 1080 pixels in size and 4 seconds in duration. The camera pans were filmed by drones, hand-held cameras, cameras on tripods, and bodycams. The simulated pans artificially pan across still images, to create a pan visual effect. The pan speeds for the simulated pans are based on the pan speed of 20 reference videos, drawn from professional, amateur, and security footage. The reference videos were distributed normally about a mean of 0.626 IPS and a standard deviation of 0.463. This distribution and a random number generator were used to select speeds for the simulated pans. Negative numbers were replaced with zero, which produced videos with no motion (i.e., still images).

Experiment **its4s4** also considers whether the quality of a camera pan is impacted by the video's frame rate, measured in frames per second (fps). Simulated pan speed videos were created with frame rates ranging from 24fps to 120fps, as noted in Table 1. The selection of real camera pans was limited by content availability,

Table 1. Frame Rate of Simulated Pans and Camera Pans

FPS	**24**	**30**	**50**	**60**	**120**
Number of Simulated Pans	21	21	21	21	16
Number of Camera Pans	32	57	0	7	0

The simulated and real pan videos were mixed together and split into three groups: a training session and two test sessions. Nine videos were used as a training session for both groups prior to the test. These training videos depict the wide variety of different videos and pan speeds that would be experienced through the test. The two test sessions each have 98 videos, and subjects viewed and rated only one test session.

Both sessions have approximately the same distribution of pan speed, frame rate, camera pans, and simulated pans. Subjects for both sessions were recruited from the same set of participants

and the same venue. Thus, data from both sessions can be combined into one dataset without further scaling.

The experiment adhered to ITU-T Rec. P.913. All videos were rated using a modified version of the absolute category rating (ACR) scale that includes a "skip" option in addition to the standard rating levels, which are excellent, good, fair, poor, and bad. Several rounds of preliminary testing were conducted with Department of Commerce Boulder Labs employees. Based on this feedback, more fast pans were added to the experiment.

Subjects were recruited at the 2019 Public Safety Communications Research (PSCR) Public Safety Broadband Stakeholder Meeting. As thanks for their participation, subjects were given a $10 gift certificate and a stylus pen. The **its4s4** videos were rated by 49 people total, 24 or 25 people per clip depending on the session. The actual number of ratings per clip is slightly lower; when subjects used the "skip" option, no rating is recorded.

The experiment was conducted on four identical laptops with touchscreens that fold into a tablet form factor. These same laptops were used for the **its4s3** experiment. The experiment was controlled by the AVRateNG software [5]. Two laptops had one session, and the other two laptops had the other session. These four laptops were arranged around a table in room with artificial lighting. There was light crowd noise from an adjacent room with diverse demonstrations. Most subjects used the stylus with the laptop mode; only a few folded the laptop into a tablet. Viewing distance was selected by the subject and not measured. A picture of the room is not available.

After signing a release form, subjects were given brief verbal instructions. Written instructions had been prepared and were available, but only one subject bothered to read them. At the previous year's Stakeholder meeting, we observed that subjects were loath to read even brief instructions during a busy meeting where numerous talks and demonstrations were available. Verbal instructions were provided to ensure subjects had some instruction on the task.

The experiment proctor attempted to give all subjects similar instructions. The goal of our research was described as intelligent cameras that understand the quality of video that first responders need to do their jobs. The subject was asked to rate videos from the viewpoint of a first responder using a live video feed to make real-time decisions in a mission critical situation. The remainder of the instruction was a brief description of the user interface, format (i.e., training session followed by experiment session), expected experiment duration (10 to 15 minutes), rating scale, the lack of audio, the availability of touch screen, and that everyone's opinions would differ. No constraints were made on how to rate videos. If a subject asked what "good quality" meant, for example, they were asked to use their own judgement. Subjects were asked to use the skip button if their attention wandered and they did not see the video. Subjects were told that this happens to everyone occasionally.

Subjects were asked to supply a bit of demographic information on a separate piece of paper, but unfortunately data entry errors occurred. Some demographic information is missing, and we cannot be sure the subject ID numbers in the demographic information perfectly correspond to the subject ID numbers in the rating data. Therefore, the demographic information is summarized in Table 2 and not distributed with the dataset.

Table 2. Subject Demographics

Age							
Years	18..24	25..29	30..39	40..49	50..59	60..69	70+
Number of Subjects	4	0	15	9	8	11	0
Vision							
Self-Assessment	Excellent	Good	Fair	Poor	Bad		
Number of Subjects	20	25	2	0	0		
First Responder							
Current or Retired First Responder	Yes	No					
Number of Subjects	22	26					

3. MEAN OPINION SCORE ANALYSIS

Recall that subjects were asked to select "skip" if they did not see a video. Table 1 shows how often subjects used this rating option—76% of subjects (37 out of 49) never used the "skip" rating level. The subject who selected "skip" most often used this option for 6% of the data (6 out of 99 votes). Most subjects (48 out of 49, or 98%) used the "skip" option for 5% or less of the data (5 or fewer out of 99 votes). This is consistent with **its4s3** and **its4s**, where 97% and 100% of subjects respectively used the "skip" option for 5% or less of the data.

Table 3. "Skip" Rating Level

"Skip" use frequency	**0%**	**1%**	**2%**	**3%**	**4%**	**5%**	**6%**
Number of Subjects	37	6	1	2	2	2	1

Figure 1 shows the distribution of Pearson correlations between mean opinion score (MOS) and each subject's ratings. The mean of this distribution is lower than typically seen in subjective experiments that use the traditional full-matrix design with repeated scenes (e.g., encode each source video sequence at multiple bitrates, or add different amounts of Gaussian noise to each image). Experiments **its4s2** and **its4s3** also have lower subject correlations than a typical full-matrix experiment. We believe that this higher diversity of opinion is associated with the unrepeated scene design and camera impairments. Since this appears to be a characteristic of the experiment design, and not a flaw in the subject's rating behavior, we cannot support discarding any of the subjects' data.

Figure 2 shows the distribution of MOS for each session, presented as a normalized frequency histogram. Each session has a roughly even distribution of ratings between excellent and poor (5.0 to 2.0 MOS).

Figure 3 plots MOS versus standard deviation of scores (SOS). This scatter plot shows the expected relationship (i.e., lower SOS as MOS approaches maximum and minimum).

Figure 4 plots pan speed versus MOS, for the videos with simulated pans. Based on this graph and an analysis of variance, we see no evidence that the quality of the pan is influenced by frame rate. The rapid drop in quality of ≈4.5 MOS at 0 IPS to ≈2.5 MOS at 0.6 IPS shows why professional videographers use tripods and often film with their hands off the camera. Notice that the best videos received ≈4.5 MOS (which is typical for the ACR scale) and the fastest pans receive ≈2.0 MOS. This leaves approximately ¼ of the MOS scale to differentiate from a fast pan (with no other impairments) and the bottom of the MOS scale. While we know that the ACR experiments do not produce absolute MOSs, we can still expect diminishing quality loss when other impairments are added to a fast pan. Therefore, if we want an NR metric to accurately predict quality between poor and bad for camera capture impairments, we will need training data that includes medium and fast pans confounded with a variety of other camera capture problems (e.g., white level, poor focus, noise from low light levels). This will be particularly important for first responder applications, as bodycams and security cameras commonly produce fast pans. The single impairment experiment design proposed in this document will not be helpful for understanding this relationship.

Also, this analysis omits the confounding factor of the shutter speed and motion blur, which often differs for photographs and videos. Motion blur refers to the blurry edges of moving objects, when compared to the sharp edges of still objects. A frame from a professional video camera, displayed freeze-framed, typically contains more motion blur than a photograph from a digital single-lens reflex (DSLR) camera. This intentional blur of moving edges enhances the video quality (i.e., the motion appears more smooth, less jerky). The simulated pans in **its4s4** were created from photographs, and thus have lower levels of blur around moving objects than we would expect from a typical video camera. While the relationship depicted in Figure 4 is less accurate than the scatter of data implies, this source of error is small when compared to the overall accuracy of the currently available NR metrics.

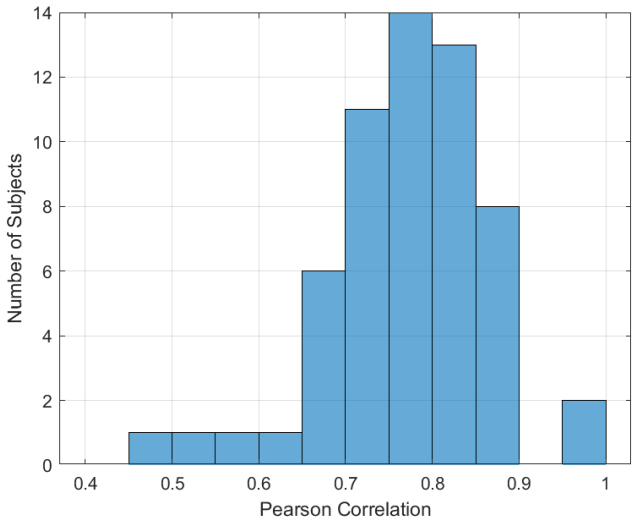

Figure 1. Pearson Correlations between session MOSs and each subject's ratings.

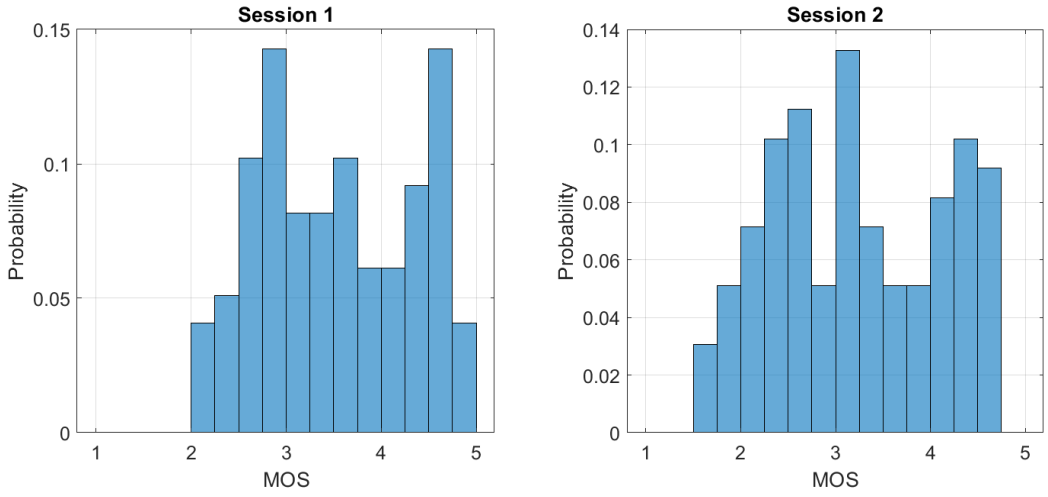

Figure 2. Distribution of MOSs.

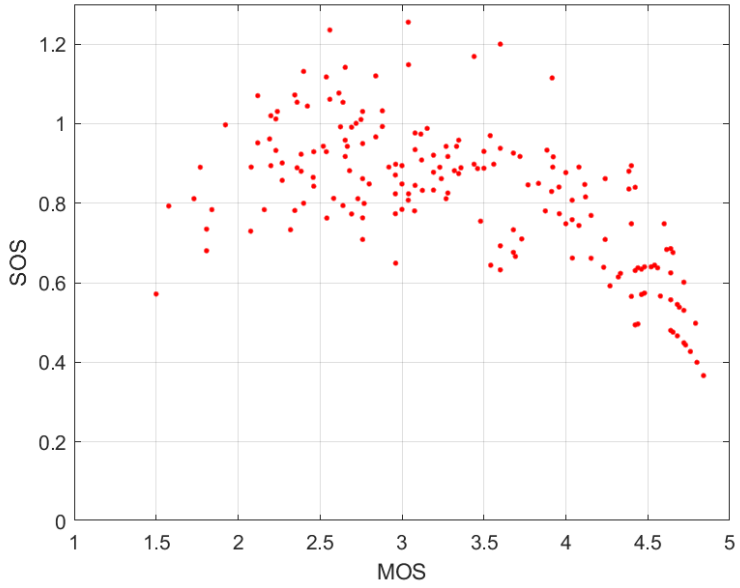

Figure 3. MOS versus SOS.

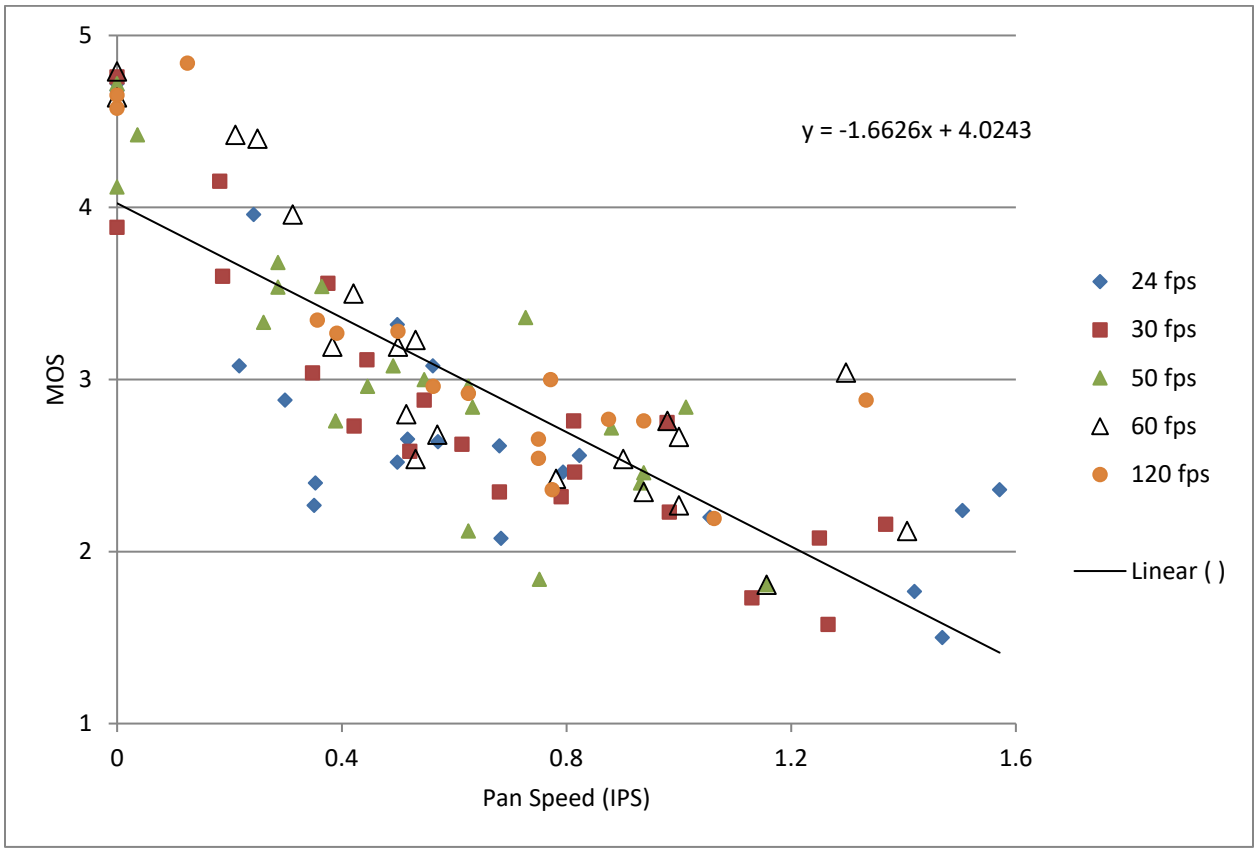

Figure 4. Relationship between pan speed and MOS, based on pans simulated from photographs.

4. DATASET DISTRIBUTION

The **its4s4** dataset will be made available in the near future on the Consumer Digital Video Library (CDVL, www.cdvl.org) for research and development purposes. CDVL provides:

- The 4 second videos, as viewed and rated by the subjects
- The 4 second videos, converted to uncompressed AVI
- Subjective ratings
- Image attribution, with Flickr website address

The **its4s4** dataset is intended specifically to inspire innovative NR metric development around camera capture and public safety applications. The experiment design emphasizes a large variety of unrepeated content and camera capture impairments.

5. REFERENCES

[1] Margaret H. Pinson, "ITS4S: A Video Quality Dataset with Four-Second, Unrepeated Scenes," NTIA Technical Memo TM-18-532, February 2018.

[2] Margaret H. Pinson, "ITS4S2: An Image Quality Dataset With Unrepeated Images From Consumer Cameras," NTIA Technical Memo 19-537, .

[3] Margaret H. Pinson, "ITS4S3: A Video Quality Dataset With Unrepeated Videos, Camera Impairments, and Public Safety Scenarios," NTIA Technical Memo, 19-538.

[4] The White House, "Executive Order—Making Open and Machine Readable the New Default for Government Information," May 09, 2013, <https://obamawhitehouse.archives.gov/the-press-office/2013/05/09/executive-order-making-open-and-machine-readable-new-default-government-> Accessed May 23, 2018.

[5] Steve Göring, Maximilian Schaab, Serge Molina, and Anton Schubert, "AVRateNG—next generation of AVRate," Technical University of Ilmenau and Deutsche Telekom AG, <https://github.com/Telecommunication-Telemedia-Assessment/avrateNG> Accessed May 23, 2018.

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[7] Andrew Weinert, "Video and Imagery Dataset to Drive Public Safety Capabilities," *Public Safety Broadband Stakeholder Meeting*, July 10, 2019. <https://www.nist.gov/ctl/pscr/psiap-new-jersey>

ACKNOWLEDGEMENTS

This work was funded by the Public Safety Communications Research (PSCR) Division of the National Institute of Standards and Technology (NIST).

APPENDIX A INFORMED CONSENT FORM

Camera Pan Experiment

The Institute for Telecommunication Sciences (ITS) is conducting a subjective video quality experiment. The results of this experiment will help us understand the quality impact of camera pans on video used for situational awareness.

Each subject will sit on a comfortable chair and watch 4 second videos on a laptop. Subjects will specify their opinion of the video quality. The participants of this experiment are not expected to experience any risk or discomfort. This experiment conforms to ITU-T Recommendation P.913 "Methods for the subjective assessment of video quality, audio quality and audiovisual quality of internet video and distribution quality television in any environment."

During the experiment, we ask you to imagine that you are monitoring a situation remotely and making real-time, mission critical decisions. Your participation is expected to be 15 min, including receiving instruction, rating videos, and answering a short questionnaire.

This experiment will take place July 9 to 11, 2019, at the 2019 PSCR Public Safety Broadband Stakeholder Meeting. If extra data is needed, subjects will be recruited from Boulder, CO, from July 15 to 31. This experiment will involve no more than 30 people. The identities of subjects will be kept confidential. Your ratings and feedback will be identified by a number you choose at the beginning of the experiment.

Participation in this experiment is entirely voluntary. Refusal to participate will involve no penalty, and you may discontinue participation at any time. If you have any questions about research subjects' rights, or in the event of a research-related injury to the subject, please contact Lilli Segre at (303) 497-3572. If you have any questions about this experiment or our video quality research, please contact Margaret Pinson at (303) 497-3579 or email address mpinson@ntia.doc.gov. Subjects will be thanked for your participation with a $10 gift certificate and a stylus pen. Federal employees cannot receive the gift certificate.

Please sign below to indicate that you have read the above information and consent to participate in this video quality experiment.

APPENDIX B PHOTOGRAPH ATTRIBUTION AND USAGE RIGHTS

This appendix contains attribution and licensing terms for the **its4s4** videos. Table 4 contains attribution information and licensing terms for the images taken from Flickr for this experiment. Website links to the Flickr pages are available in a spreadsheet distributed with the **its4s4** dataset. Table 5 contains attribution information for the remaining media: videos edited from footage commissioned by ITS, images that appeared in **its4s2**, and videos that appeared in **its4s3**. See [2] and [3] for attribution and licensing terms for media from **its4s2** and **its4s3** respectively.

Four sequences were created jointly by the Massachusetts Institute of Technology's (MIT) Lincoln Laboratory and the New Jersey Office of Homeland Security. See [6] and [7] for more information on this footage. These sequences are distributed under the Creative Commons 4.0 public license (https://creativecommons.org/licenses/by/4.0/legalcode) with this additional clause:

> "This work was performed under the following financial assistance award 70NANB17Hl69 from U.S. Department of Commerce, National Institute of Standards and Technology. DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited. (C) 2019 Massachusetts Institute of Technology. Delivered to the U.S. Government with Unlimited Rights, as defined in DFARS Part 252.227-7013 or 7014 (Feb 2014). Notwithstanding any copyright notice, U.S. Government rights in this work are defined by DFARS 252.227-7013 or DFARS 252.227-7014 as detailed above. Use of this work other than as specifically authorized by the U.S. Government may violate any copyrights that exist in this work."

All other videos adhere to the CDVL licensing terms (see www.cdvl.org). The aforementioned ITS footage is as follows:

- The "2007 University of Colorado at Boulder (CU) football stadium crowds" footage depicts stadium seating during a football game at the University of Colorado at Boulder. This footage was made possible by a joint collaboration between NTIA's Institute for Telecommunication Sciences (ITS) and the National Institute for Science and Technology (NIST) division then known as the Office of Law Enforcement Standards.

- The "2010 Emergency Medical Service (EMS)" footage contains realistic simulations of common EMS responses. The goal was to promote research and development into the use of video for emergency medical response. This EMS footage was choreographed, filmed and contributed through the cooperative efforts of the National Association of State EMS Officials, the Western Eagle County Ambulance District of Colorado, Tristate CareFlight 15, the General Eagle Fire Protection District, Big Steve's Towing, and a joint collaboration between NTIA/ITS and the NIST division then known as the Office of Law Enforcement Standards.

- The "PSCR 2017 Drone LaCie Firefighter Training" footage depicts firefighter training, filmed simultaneously by a professional drone and a professional video camera. This footage was created to enable subjective experiments that focus on the needs of first responders. See **its4s3** for more information.

Table B-1. Video Footage Attribution

File Name	Owner	Licensing terms	Name of Photo	Camera	Date Accessed
pan-test1	Los Angeles Fire Department	Non Commercial, Share Alike	LAFD Welcomes Recruit Training Academy Class 2016-3	Nikon D3	5/21/2019
pan-test2	Los Angeles Fire Department	Non Commercial, Share Alike	LAFD Welcomes Recruit Training Academy Class 2016-3	Nikon D3	5/21/2019
pan-test3	Los Angeles Fire Department	Non Commercial, Share Alike	LAFD Welcomes Recruit Training Academy Class 2016-3	Nikon D3	5/21/2019
pan-test4	Los Angeles Fire Department	Non Commercial, Share Alike	LAFD Welcomes Recruit Training Academy Class 2016-3	Nikon D800	5/21/2019
pan-test5	U.S. Department of Agriculture	Public Domain	20160823-FS-LSC-1268	Nikon D4	5/21/2019
pan-test6	Paul Nicholson	Non Commercial, Share Alike	Queen's Chess Panorama	Nikon D90	5/21/2019
pan-test7	Steve Braund	Non Commercial, Share Alike	Flooded	Cannon EOS 450D	5/21/2019
pan-test8	Paulo Fierro	Non Commercial, Share Alike	Cowd	Panasonic DMC LX3	5/21/2019
pan-test9	U.S. Army Garrison Yongsan	Non Commercial, Share Alike	MA SCAL exercise tests first responders	Nikon D5000	5/21/2019
pan-test10	Mussi Katz	Public Domain	up SIDE down	Cannon EOS REBEL	5/21/2019
pan-test11	Camp Heumensoord	Non Commercial, Share Alike	Oefening Medic Diamond	Cannon EOS-1Dx	5/21/2019
pan-test12	Camp Heumensoord	Non Commercial, Share Alike	Oefening Medic Diamond	Cannon EOS-1Dx	5/21/2019
pan-test13	cclark395	Non Commercial, Share Alike	NAS Fallon "Longhorns"	Pentax K-5	5/21/2019
pan-test14	NightFlightToVenus	Non Commercial, Share Alike	Firefighters	Cannon EOS 60D	5/21/2019
pan-test15	Divine Harvester	Non Commercial, Share Alike	n/a	n/a	5/21/2019
pan-test16	Thomas Hawk	Non Commercial, Share Alike	Oakland Police	Cannon EOS 5D Mark II	5/21/2019
pan-test17	National Law Enforcement Memorial Day	Non Commercial, Share Alike	2015 National Police Week 5K	Nikon D5100	5/21/2019

File Name	Owner	Licensing terms	Name of Photo	Camera	Date Accessed
pan-test18	Thomas Hawk	Non Commercial, Share Alike	American Firefighter	Cannon EOS 5D Mark II	5/21/2019
pan-test19	Intermountain Forest Services	Public Domain	Bonneville Hotshots 2016_08_30-09.05319.396-CDT	n/a	5/21/2019
pan-test20	Airman Magazine	Non Commercial, Share Alike	120628-F_JQ435-032	Nikon D700	5/21/2019
pan-test21	Forest Service, USDA	Public Domain	20180811-FS-Rogue-KG-0517	n/a	5/21/2019
pan-test22	Airman Magazine	Non Commercial, Share Alike	120628-F-JQ435-036	Nikon D700	5/21/2019
pan-test23	Ella	Non Commercial, Share Alike	A disability rights protest	Olympus E-M5	5/21/2019
pan-test24	Thomas Hawk	Non Commercial, Share Alike	Oakland	Cannon EOS 5D Mark II	5/21/2019
pan-test25	Thomas Hawk	Non Commercial, Share Alike	Oakland 2010	Cannon EOS 5D Mark II	5/21/2019
pan-test26	Can Pac Swire	Non Commercial, Share Alike	Crew from Rescue 326	Cannon EOS REBEL T2i	5/21/2019
pan-test27	CherryPoint	Non Commercial, Share Alike	Aircraft rescue firefightrers battle blazes, sustain skills	Cannon EOS 5D Mark II	5/21/2019
pan-test28	Cal OES	Non Commercial, Share Alike	Multi-agency Controlled Burn June 2018	n/a	5/21/2019
pan-test29	Matt Hecht	Public Domain	140211-Z-NI803-062	Cannon EOS 7D	5/21/2019
pan-test30	Thomas Hawk	Non Commercial, Share Alike	Oakland 2010	Cannon EOS 5D Mark II	5/21/2019
pan-test31	Justin Norman	Non Commercial, Share Alike	Witness Against Torture: Jeremiah Arrested	Cannon EOS 5D Mark II	5/21/2019
pan-test63	Photospector	Non Commercial, Share Alike	IMG_8248	Cannon EOS 1100D	5/24/2019
pan-test64	Photospector	Non Commercial, Share Alike	IMG_8251	Cannon EOS 1100D	5/24/2019
pan-test65	Jungfrau Marathon	Non Commercial, Share Alike	JUNGFRAU-MARATHON 2008	Cannon EOS-1Ds Mark II	5/24/2019
pan-test66	nico1959	Non Commercial, Share Alike	2013_09_14_3652	Cannon EOS 450D	5/24/2019
pan-test67	Thomas Marthinsen	Non Commercial, Share Alike	20090110_165354	Nikon D700	5/24/2019

File Name	Owner	Licensing terms	Name of Photo	Camera	Date Accessed
pan-test68	National Law Enforcement Memorial Day	Non Commercial, Share Alike	2015 National Police Week 5K	Nikon D5100	5/24/2019
pan-test69	blogcram	Non Commercial, Share Alike	2014-05-07_90)_19h55	Cannon EOS REBEL T5i	5/24/2019
pan-test70	Grand Island Area Habitat for Humanity	Non Commercial, Share Alike	Burn Feb 2017_0163	Cannon EOS 6D	5/24/2019
pan-test71	Grand Island Area Habitat for Humanity	Non Commercial, Share Alike	Burn Feb 2017_0227	Cannon EOS 6D	5/24/2019
pan-test72	Grand Island Area Habitat for Humanity	Non Commercial, Share Alike	Burn Feb 2017_0066	Cannon EOS 6D	5/24/2019
pan-test73	NightFlightToVenus	Non Commercial, Share Alike	Firefighters	Cannon EOS 60D	5/24/2019
pan-test74	Thomas Hawk	Non Commercial, Share Alike	American Firefighter	Cannon EOS 5D Mark II	5/24/2019
pan-test75	Chiang Kai Yen	Non Commercial, Share Alike	DSC_7963	n/a	5/24/2019
pan-test76	Thomas Hawk	Non Commercial, Share Alike	American Firefighter	Cannon EOS 5D Mark II	5/24/2019
pan-test77	Bundersheer Fotos	Non Commercial, Share Alike	n/a	Nikon D750	5/24/2019
pan-test78	Fernando Tatagiba	Non Commercial, Share Alike	775A8990	Cannon EOS 5D Mark II	5/24/2019
pan-test79	Forest Service, USDA	Public Domain	20130809-FS_LSC_0344	Nikon D800	5/24/2019
pan-test80	U.S. Foreset Service-Pacific Northwest Photostream	Public Domain	Firefighters conducting burnout operation	n/a	5/24/2019
pan-test81	U.S. Foreset Service-Pacific Northwest Photostream	Public Domain	20180820_FS_Okanogan_KG_1235	n/a	5/24/2019
pan-test82	Forest Service, USDA	Public Domain	20160827-FS-Boise-KG-100	n/a	5/24/2019
pan-test83	Los Angeles Fire Department	Non Commercial, Share Alike	LAFD Welcomes Recruit Training Academy Class 2016-3	Nikon D800	5/24/2019
pan-test84	Kirill Ignatyev	Non Commercial, Share Alike	Flood	Olympus E-PL1	5/24/2019

File Name	Owner	Licensing terms	Name of Photo	Camera	Date Accessed
pan-test85	Camp Heumensoord	Non Commercial, Share Alike	Oefening Medic Diamond	Cannon EOS-1DX	5/24/2019
pan-test86	Sorin Mutu	Non Commercial, Share Alike	Bucegi Mountains	n/a	5/24/2019
pan-test87	Michal Oravec	Non Commercial, Share Alike	Vysoke Tatry mountains	Olympus FE-130, X-720	5/24/2019
pan-test88	NPS Natural Resources	Public Domain	Mountains	n/a	5/24/2019
pan-test89	gaurav76	Non Commercial, Share Alike	yosemite_0248	Cannon EOS 5D Mark II	5/24/2019
pan-test90	Richard Schneider	Non Commercial, Share Alike	Winter Landscape Austria	Sony ILCE-7RM3FE 24-105mm F4G OSS	5/24/2019
pan-test91	Mitchell Cipriano	Non Commercial, Share Alike	Three Brothers	Nikon D800	5/24/2019
pan-test92	Mark Robinson	Non Commercial, Share Alike	Exmoor Waterfall	Cannon EOS Digital Rebel Xsi	5/24/2019
pan-test93	K Tempest Bradford	Non Commercial, Share Alike	Bridal Veil - Columbia River Gorge	n/a	5/24/2019
pan-test94	jurek d.	Non Commercial, Share Alike	Into the light	n/a	5/24/2019
pan-test95	Jean Zar	Non Commercial, Share Alike	Tenous ending	n/a	5/24/2019
pan-test96	Erik de Haan	Non Commercial, Share Alike	Poland, Bialowieska forest, fallen tree in deciduous lime-hornbean-oak forest	Cannon Powershoot SX200 IS	5/24/2019
pan-test97	myhnyr	Non Commercial, Share Alike	Fairy forest	Cannon EOS 60D	5/24/2019
pan-test98	Angelo Brathot	Public Domain	three islands in the pond	Cannon EOS 6D	5/24/2019
pan-test99	Ales Krivec	Non Commercial, Share Alike	Lake Limides	n/a	5/24/2019
pan-test100	Divine Harvester	Non Commercial, Share Alike	n/a	n/a	5/24/2019

Table B-2. Image Attribution

File Name	Source
Broadcast_076-Bsrc13K_SRC.mp4	its4s3
Chance_006-Csrc26C_SRC.mp4	its4s3
Chance_017-Csrc26H_SRC.mp4	its4s3
Chance_021-Csrc26B_SRC.mp4	its4s3
Chance_023-Csrc26B_SRC.mp4	its4s3
Chance_049-Csrc15C_SRC.mp4	its4s3
Everglades_008-Esrc33E_SRC.mp4	its4s3
Everglades_014-Esrc33G_SRC.mp4	its4s3
Everglades_040-Esrc33G_SRC.mp4	its4s3
Everglades_047-Esrc33G_SRC.mp4	its4s3
Everglades_090-Esrc33G_SRC.mp4	its4s3
Everglades_095-Esrc33G_SRC.mp4	its4s3
its4s3_cs-pan-16_blur.mp4	its4s3
its4s3_cw-pan-76_object.mp4	its4s3
its4s3_cw-pan-77_temporal.mp4	its4s3
its4s3_cw-pan-83_motion.mp4	its4s3
its4s3_cw-pan-93_codec.mp4	its4s3
its4s3_fg-drive-70_motion.mp4	its4s3
its4s3_fg-drive-72_object.mp4	its4s3
its4s3_fg-drive-73_motion.mp4	its4s3
its4s3_fg-drive-74_contrast.mp4	its4s3
its4s3_fg-pan-26_motion.mp4	its4s3
its4s3_fg-pan-79_contrast.mp4	its4s3
its4s3_pr-pan-39_motion.mp4	its4s3
its4s3_pr-pan-41_motion.mp4	its4s3
its4s3_pr-pan-45_lensflare.mp4	its4s3
its4s3_pr-pan-79_motion.mp4	its4s3
its4s3_pr-pan-80_motion.mp4	its4s3
its4s3_sr-drone-10_texture.mp4	its4s3
its4s3_sr-drone-12_motion.mp4	its4s3
its4s3_sr-drone-15_motion.mp4	its4s3
its4s3_sr-drone-20_motion.mp4	its4s3
its4s3_sr-drone-24_dof.mp4	its4s3

File Name	Source
its4s3_sr-walk-75_contrast.mp4	its4s3
its4s3_vw-drone-99_texture.mp4	its4s3
Music&Mexico_012-Msrc01D_SRCpls.mp4	its4s3
Music&Mexico_037-Msrc02I_SRC.mp4	its4s3
Music&Mexico_054-Msrc02U_SRC.mp4	its4s3
Nature_075-Nsrc34S_SRC.mp4	its4s3
Nature_079-Nsrc34S_SRC.mp4	its4s3
pan-emt01.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt02.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt03.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt04.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt05.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt07.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt08.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt09.mp4	2010 Emergency Medical Service (EMS) footage
pan-emt10.mp4	2010 Emergency Medical Service (EMS) footage
pan-firefighter00.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter01.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter04.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter05.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter06.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter07.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter08.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter09.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter10.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter12.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter13.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter14.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter15.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter16.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter18.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter19.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter20.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter21.mp4	PSCR 2017 Drone LaCie Firefighter Training

File Name	Source
pan-firefighter22.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter24.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter25.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter26.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter27.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter28.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter29.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter30.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter31.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter32.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter33.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter35.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter36.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-firefighter38.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-football02.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football03.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football04.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football05.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football06.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football08.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football10.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football12.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football14.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football15.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football17.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds
pan-football18.mp4	2007 University of Colorado at Boulder (CU), football stadium crowds

File Name	Source
pan-mit1.mp4	MIT Lincoln Laboratory and New Jersey Office of Homeland Security [3]
pan-mit2.mp4	MIT Lincoln Laboratory and New Jersey Office of Homeland Security
pan-mit3.mp4	MIT Lincoln Laboratory and New Jersey Office of Homeland Security
pan-mit4.mp4	MIT Lincoln Laboratory and New Jersey Office of Homeland Security
pan-test101.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test102.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test103.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test104.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test105.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test106.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test107.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test108.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test109.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test110.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test111.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test112.mp4	PSCR 2017 Drone LaCie Firefighter Training
pan-test32.avi	its4s2
pan-test33.mp4	its4s2
pan-test34.mp4	its4s2
pan-test35.avi	its4s2
pan-test36.mp4	its4s2
pan-test37.mp4	its4s2
pan-test38.mp4	its4s2
pan-test39.mp4	its4s2
pan-test4.mp4	its4s2
pan-test40.avi	its4s2
pan-test41.mp4	its4s2
pan-test42.mp4	its4s2
pan-test43.mp4	its4s2
pan-test44.mp4	its4s2

[3] The MIT Lincoln Laboratory footage is distributed under the Creative Commons 4.0 license with an additional clause, as noted at the beginning of this appendix.

File Name	Source
pan-test45.avi	its4s2
pan-test47.mp4	its4s2
pan-test48.mp4	its4s2
pan-test49.mp4	its4s2
pan-test5.avi	its4s2
pan-test50.mp4	its4s2
pan-test51.avi	its4s2
pan-test52.mp4	its4s2
pan-test53.mp4	its4s2
pan-test55.mp4	its4s2
pan-test56.mp4	its4s2
pan-test57.mp4	its4s2
pan-test58.mp4	its4s2
pan-test6.mp4	its4s2
pan-test60.mp4	its4s2
pan-test61.mp4	its4s2
pan-test62.mp4	its4s2

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14. SUPPLEMENTARY NOTES

15. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

This technical memorandum provides technical details for the video quality subjective experiment **its4s4**. This experiment includes 196 videos, each 4 seconds in duration, depicting camera pans at different speeds. Other impairments are avoided where possible. This experiment implements an unrepeated scene design, so each 4 second video contains unique content. The **its4s4** dataset provides training data for no-reference video quality metrics that predict quality impairments associated with camera pan speed. The dataset is freely available for research and development purposes.

16. Key Words (Alphabetical order, separated by semicolons)

abstract; appendix; conclusion; document; figures; format; heading; introduction; policy; references; style guide; tables

17. AVAILABILITY STATEMENT	18. Security Class. (This report)	20. Number of pages
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