Fearless Steps APOLLO: Operational Disconnect Detection in Mission Control

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I. Abstract

Teams engaged in complex real-time tasks such as air traffic control [1], emergency medicine [5], or military operations [6] rely on task coordination between specialized experts, in part using voice communication. Bearman, et al. studied incidents of operational, evaluative, and informational disconnects in radio communication between the Mission Control Center (MCC) and the spacecraft during the Apollo 13 mission, with the ultimate goal of studying the resolution of those disconnects and their effect on decision making [1]. In that study, they identified a total of 204 such disconnects. In our new work, we focus on operational disconnects observed on three recorded Apollo 13 MCC channels: the Flight Director loop, Flight Dynamics Officer (FIDO) headset audio, and Network Controller headset audio. Operational disconnects are defined as (1) a difference between the actions of one party and actions expected by the other party, or (2) a mismatch in the plans each party had about some operation. Plans are action-oriented cognitive structures that encapsulate intentions about future behavior.

We used two cue phrases ("don't want to", "don't do that") to identify several hundred regions of Ben Feist's Whisper Automatic Speech Recognition (ASR) transcripts [2] that might be associated with operational disconnects. Manual inspection indicated that transcribed terms are very often correct despite the challenging conditions, with a word error rate well below 5% (after excluding stopwords). However, readability was adversely affected by speaker turns often being conflated as a single utterance. A second challenge was that for headset audio channels there were often several loops (intercom or radio circuits) being monitored simultaneously, so transcripts could intermix words from more than one loop. Annotation was therefore performed using audio from Ben Feist's Apollo in Real Time website [3]. Except for cases that could be clearly excluded based on the transcript, this was done by manually setting a replay start time prior to where the cue phrase had been found in the transcript and then listening.

Annotation was performed on 306 cases by the third author, who is knowledgeable on Apollo 13 but previously unfamiliar with the annotation task. As training, the second and third authors coded 15 examples together, discussing whether a disconnect was present and interpretation of the definition of an operational disconnect. Notes from this process are in Fig. 1. The third author then independently coded the remaining cases, finding a total of 56 of 306 cases (including training cases) to be operational disconnects, 23 to be unclear, and 227 not to be operational disconnects. Of these, 4 disconnects occurred before launch, and 7 others were serendipitously discovered despite lacking a cue phrase. Figs. 2 and 3 illustrate positive and negative examples. Finally, 15 cases not used for training were randomly selected and independently coded by the second author, finding very high agreement (kappa=0.86).

Automating disconnect detection could alert team members to situations that might benefit from additional attention for proactive prevention of coordination breakdowns. To explore the extent to which detection of operational disconnects could be automated, we used 5-fold cross-validation to train and evaluate a scikit-learn linear kernel Support Vector Machine (SVM) classifier [4] on a balanced set of 45 positive examples (excluding those without cue phrases and those before launch) and 45 negative examples selected from similar times in the mission, using TFIDF features on WordNet lemmas for non-stopwords in the utterance containing the cue phrase. The resulting balanced accuracy, 0.61 ± 0.02, was achieved despite not having channel separation, acoustic features, or broader context. This suggests that real-time automated disconnect detection may to some degree be feasible.

In future work we plan to annotate additional channels, to extend our annotation to informational and evaluative disconnects, to investigate richer models, to explore the potential for training disconnect detectors on one mission (e.g., Apollo 11) and then testing them on a later mission, to use the annotations we create (both manually and automatically) to study instances of coordination breakdowns and mechanisms for recovery from coordination breakdowns, and to consider human-system design options for the real-time use of automated disconnect detection.

1. If they are discussing a plan in a collaborative style and posing questions designed to explore the problem in more detail to determine a solution or pathway forward, this is not a disconnect.
2. If one entity is proposing a procedure or pathway forward and it is countered or rebutted, then this is an example of a disconnect (this may be conveyed by the tone of voice used by one or more of the participants).
3. If changes are made to an existing plan and there is no conflict or disagreement with the proposed change, then this is not a disconnect.
4. If the tone of a response indicates a potential disconnect where the other party is either off-loop or the conversation has occurred off comms, there is insufficient evidence to support there being a disconnect.
5. The term matching occasionally generates overlapping segments with very similar times. These duplicates were ignored.
6. When simultaneous speech from two or more monitored loops prevents clear understanding in headset audio, the passage is annotated as not an operational disconnect.

Fig. 1. Annotation notes.

FLIGHT DIRECTOR LOOP (channel 50) matching regular expression: "don't want to"

062:00:18 Are you ready to proceed and power the computer down?
062:00:21 Negative, I do not want to power the computer down.
062:00:23 Why not?
062:00:24 Well, I'm being told that we can leave it up for the sleep period and it'll keep their energy before I keep them out of gimbal lock.
062:00:32 The computer also?
062:00:33 Yes, that's what I'm being told, the LGC.
062:00:41 Okay, so you're talking about leaving the computer up also, huh? Affirmative.
062:00:44 And that's okay on the profile?
062:00:46 That's affirmative.
062:00:48 It's about 22 amps total.
062:00:50 And what kind of control mode do you see them being in here tonight?
062:00:53 Okay, just in a five degree dead band attitude hull.
>>>062:00:57 Wait a minute, we [[[don't want to]]] be in attitude hull.
062:00:59 We want to roll.
062:01:00 Oh, you want to let roll go?
062:01:01 But you can't let roll go.
062:01:04 It's going to be an at-hull.
062:01:06 Okay, but how, can we fly an at-hull the whole time?
062:01:10 We're going to burn something up?
062:01:12 I've got the question in, I haven't got an answer on it yet, Flight.

Fig. 2. Example of a passage from the Apollo 13 Flight Director loop ASR transcript that was annotated as an operational disconnect. Times are Ground Elapsed Time (GET) since launch, in hours:minutes:seconds. [[[…]]] indicates the cue phrase.

NETWORK CTRLR [R] (channel 11) matching regular expression: "don't want to"

071:30:41 I take it you've heard about this TV conference or whatever it is that's coming up here shortly?
071:30:59 Not really. Chuck just wanted to know if I knew anything about it, and I don't.
071:31:03 Okay. You know as much as I do then. I understand we're supposed to get it to the VIP room.
071:31:08 I don't know where else, you know, who wants it or what it's for or what it is.
071:31:13 But we'll put it on channel 6 on the little color monitors in-house, and that way it'll be in the VIP room. Okay, if you say so.
>>>071:31:24 If you find out anything, let me know. Yeah, I think we're going to have to do something because if it's that kind of a conference, you probably [[[don't want to]]] distribute it anyway.
071:31:34 Okay, we'll see if we can figure out something.

Fig. 3. Example of a Network Controller headset audio ASR transcript passage that was annotated as not an operational disconnect.

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