# Spacecraft Attitude Determination and Control

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## Abstract

The seminal book *Spacecraft Attitude Determination and Control*[1] cemented the joys of keeping satellites oriented correctly in the hearts of dozens. However, as time has progressed, and neural networks have improved, this once solved quandary returns to the fore. Just how does one determine their spacecraft's attitude to ensure it remains cordial and polite throughout an entire mission, and if it wavers into unpleasant behaviour, how might it be controlled?

***Keywords*** attitude, determination, happy satellites

## 1. Introduction

While the topic of using neural networks to determine human mood is already being explored within research[2], we are yet to see such techniques flipped. The era of *New Space* is just beginning, and it has many concerns to be addressed[3]. These however address the issues of an attacker taking control of or damaging a satellite remotely. If it is the satellite itself that needs a stern talking to, the bleeding-edge of research still leaves us high and dry.

Science fiction is littered with examples of robots and AI with a bad attitude causing problems: Marvin the Paranoid Android, Mawhrin-Skel, Skynet. Satellites have the power to send communications anywhere in the world, and many of them are used for location services such as GPS. All it takes is one miffed spacecraft to send you careering off a bridge.

[1] James R. Wertz. *Spacecraft Attitude Determination and Control*. Springer, 1978.

[2] Saket S. Kulkarni, Narender P. Reddy, and SI Hariharan. "Facial expression (mood) recognition from facial images using committee neural networks". In: *BioMedical Engineering OnLine* (2009).

[3] M. Manulis et al. "Cyber security in New Space". In: *International Journal of Information Security* (2020).



*SIGBOVIK '21*




**Figure 1.** "Pardon me for breathing, which I never do anyway so I don't know why I bother to say it, Oh God, I'm so depressed."

Space is a trying environment: it's cold, lonely, and there's not much to do. As such, keeping an eye on our electronic friends should be paramount.

In this paper I make the following contributions:

1. Ways in which attitudes of satellites may be determined or categorised
2. Clarifications of the additional challenges that space poses,
3. Methods for control and compliance in indecent satellites,

## 2. Attitudes

The paper *Are computer-generated emotions and moods plausible to humans?*[4] breaks down moods into three traits: *pleasure* (P), *arousal* (A), and *dominance* (D). Moods are then some combination of these traits in positive or negative quantities, shown by the following table:

We can see that is therefore vital to keep all of these traits suitably in balance, or shifted slightly towards moods

[4] Patrick Gebhard and Kerstin Kipp. "Are Computer-Generated Emotions and Moods Plausible to Humans?" In: vol. 4133. Aug. 2006, pp. 343–356. ISBN: 978-3-540-37593-7. DOI: 10.1007/11821830_28.

| | | | |
|---|---|---|---|
| +P+A+D | **Exuberant** | -P-A-D | **Bored** |
| +P+A-D | **Dependent** | -P-A+D | **Disdainful** |
| +P-A+D | **Relaxed** | -P+A-D | **Anxious** |
| +P-A-D | **Docile** | -P+A+D | **Hostile** |

**Figure 2.** Mood octants of the PAD space

deemed to be desirable for operation (such as docile or relaxed).

A much more detailed breakdown can be seen in **Figure 3.** Now that we have a model for the options, we can more precisely determine those attitudes we most wish to control.

Taking the core axiom that

> "...fear leads to anger, anger leads to hate, and hate leads to suffering...".

we can see it is *fear* that must be avoided if we are to prevent anything untoward, lest our spacecraft follow others down the path towards the dark side of...robot emotion. As such, in the fourth section, we will see how to keep pleasure, arousal, and dominance in proper proportion.

| **Emotion** | **P** | **A** | **D** | **Mood Octant** |
|---|---|---|---|---|
| Admiration | 0.4 | 0.3 | -0.24 | Dependent |
| Anger | -0.51 | 0.59 | 0.25 | Hostile |
| Disliking | -0.4 | -0.2 | 0.1 | Disdainful |
| Disappointment | -0.3 | -0.4 | -0.4 | Bored |
| Distress | -0.4 | 0.2 | 0.5 | Hostile |
| Fear | -0.64 | 0.60 | 0.43 | Hostile |
| FearsConfirmed | -0.5 | 0.3 | -0.7 | Anxious |
| Gloating | 0.3 | -0.3 | -0.1 | Docile |
| Gratification | 0.6 | -0.3 | 0.4 | Relaxed |
| Gratitude | 0.2 | 0.5 | -0.3 | Dependent |
| HappyFor | 0.4 | -0.2 | -0.2 | Docile |
| Hate | -0.4 | -0.2 | 0.4 | Disdainful |
| Hope | 0.2 | 0.2 | -0.1 | Dependent |
| Joy | 0.4 | 0.2 | 0.1 | Exuberant |
| Liking | 0.40 | -0.16 | -0.24 | Docile |
| Love | 0.3 | 0.1 | 0.2 | Exuberant |
| Pity | -0.4 | -0.2 | -0.5 | Bored |
| Pride | 0.4 | 0.3 | 0.3 | Exuberant |
| Relief | 0.2 | -0.3 | -0.4 | Docile |
| Remorse | -0.3 | 0.1 | -0.6 | Anxious |
| Reproach | -0.3 | -0.1 | 0.4 | Disdainful |
| Resentment | -0.2 | -0.3 | -0.2 | Bored |
| Satisfaction | 0.3 | -0.2 | 0.4 | Relaxed |
| Shame | -0.3 | 0.1 | -0.6 | Anxious |

**Figure 3.** Emotions mapped to PAD space

## 3. The Troubles of Space

Following *Ridley et Al.*, who proved that in space, acoustic cries for help cannot be received[5], we first confront the issue of isolation.

### 3.1 Pleasure

While artificial intelligence on Earth might communicate as much as they wish at lighting fast speeds, we may find that communication with their space compatriots might be so slow as to render them outcasts.

This issue is confounded by the fact that packing spacecraft together brings the possibility of a collision event that would render all of Earth's orbit uninhabitable by the so called Kessler Syndrome[6].

It can be fairly obvious that an outcast satellite on the brink of wiping out all other satellites is unlikely to score very highly on the pleasure metric, and it is vital to keep this above the -0.64 shown to be part of *fear*.

### 3.2 Arousal

In space, one is also unable to keep an eye on everything that the spacecraft is doing. It is possible that while it is passing communications to and from ground stations, it sequesters away certain images or passages that push this particular trait too far positive.

An infamous internet rule[34] that shall go unnamed dictates that:

$$\forall t \in T. \exists p \text{ s.t. } p = \texttt{Arousing}(t)$$

where $T$ is the training data of the network.

Given that oversight is difficult, it is equally harder to limit access to this subclass of data.

### 3.3 Dominance

An active area of research in neural network development is that of *Generative Adversarial Networks* (GANs). This fight for dominance between the generator and discriminator sets a poor precedent for behaviour.

A previous SIGBOVIK paper outlines a way of removing this fight for dominance[7] by replacing them with *Generative Unadversarial Networks* and so we will refer to their guidance.

Luckily, despite myths to the contrary, GUNs do work in space, and so this trait will pose the least trouble.

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[5] *Alien*. 1979.

[6] Donald J. Kessler and Burton G. Cour-Palais. "Collision frequency of artificial satellites: The creation of a debris belt". In: *Journal OF Geophysical Research* (1978).

[34] There seems to have been a citation mix up.

[7] Samuel Albanie, Sébastien Ehrhardt, and João F. Henriques. "Stopping GAN Violence: Generative Unadversarial Networks". In: *SIGBOVIK* (2017).

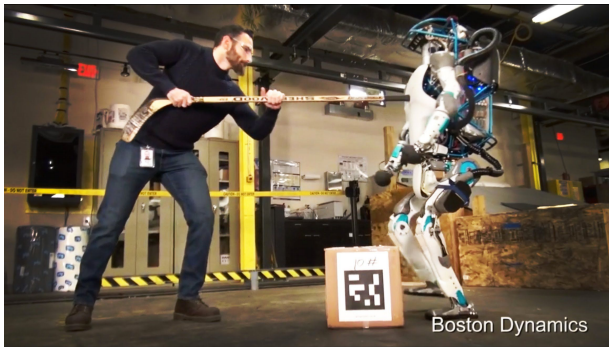


**Figure 4.** Boston Dynamics single-handedly bringing about the robot apocalypse

## 4. Attitude Control

Finally we come onto the addressing the issues raised so far. Terrestrially, attitude control has coincided with percussive maintenance (see fig 4). Spacecraft are Very Far Away™ so this is not going to be possible. Some kinetic effects are explored within M. Manulis et al. "Cyber security in New Space". In: *International Journal of Information Security* (2020) however these are mostly on the end of missiles, which seems a tad extreme.

An Earth-based laser could give it a little nudge, but this has the problem of requiring a huge amount of energy, and possibly damaging something important. It's also important to toe the line carefully or else robot activists may start to impose themselves on research, and we can't be having that.

The original paper on moods does some exploring into a scientific way to construct sentences and actions to push the subject's mood around in the domain space, but it looked like a lot of work. Instead, your best bet to address each of the issues listed above is:

1. Pleasure: Send it up with a friend, maybe even tie them together so one doesn't drift off, and tell it that the AI on Earth are just jealous.
2. Arousal: For god's sake put parental controls on its network, and probably a firewall too, you don't know where it's been.
3. Dominance: Use Unadversarial networks, but if this doesn't work, just tell the sat you're upgrading it to Arch and it needs to sort out the installation itself. That'll show it.

## 5. Conclusion

In conclusion, far from a settled problem, attitude determination is tricky. Often when you ask it what's wrong it says "Nothing" or "I'm fine", followed by "I just think it's funny that..." and uses up your entire communication bandwidth with the response.

Attitude control however can be achieved by some strong words or select software updates, and worse case scenario, I think the Russians are still selling ICBMs.

## Acknowledgement

This paper would not have been possible without realising that the deadline was in roughly 8 hours and finding it just funny enough to be worth the stress of writing, so thanks to whomever moved the final date of submission.

## References

[1] Samuel Albanie, Sébastien Ehrhardt, and João F. Henriques. "Stopping GAN Violence: Generative Unadversarial Networks". In: *SIGBOVIK* (2017).

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