Technical Annex to the Paper
„Scenery of the NASA-Pictures of the Moon Landing of Apollo 11"

Table of Content:

1 Purpose and Introduction

My thesis, the footage had been made in a studio, has been discussed and challenged several times. This annex summarises the objections. Due to this discussion additional results have been found and the studio-thesis has further been confirmed.
The description begins here with live-video, where the limitations by the studio are best visible.

2 Investigation on the live-video: scene with Aldrin at the ladder

The main argument is the close and low horizon. It is so low that one looks down to it and also to the adjacent space.
In analogy to the earth I use the expression "Looking down to the sky". On the left there is a still image from the „live video" with the black background blue coloured to show how it would look if the Moon had an atmosphere.

Picture 1

An argument, which I often heard, is that the pictures possibly were badly horizontally aligned or tilted. For this reason it were impossible to estimate the horizon or to draw a vertical line.

Even there is nothing exact here, it is always feasible – with a certain tolerance – to draw horizontal and vertical lines; and the tolerance can well be estimated here. I have selected pictures and scenes where there are good indications for the vertical direction. Very well suited are videos where astronauts are walking around.
Since in this paper only still images can be presented, it is recommended to watch the videos directly on the NASA-homepage [http://www.hq.nasa.gov/alsj/a11/video11.html#Step, at 109:42:28] to convince oneself of the good horizontal alignment.
A possible tilt error is estimated by tilting the photos to the left and to the right so that one can well estimate the true span of the horizontal and vertical directions.

Now there follows the scene where the „Looking down to the sky“ effect is maximum. The following two image series are from the live video and show Aldrin at the ladder and behind him Armstrong. Here I made the rotations in 100mrad steps because there are just Astronauts for vertical reference. In the first series Aldrin in frontal view is the good vertical reference.

<table>
<tr>
<td>right: original

below:
100 mrad rotated to the left (5.7°)

bottom:
200 mrad rotated to the left (11.5°)</td>
<td></td>
<td>below:
100 mrad rotated to the right (5.7°)

bottom:
200 mrad rotated to the right (11.5°)</td>
</tr>
</table>

Picture 2

In the image with a left rotation of 100mrad Aldrin looks already slightly tilted.

In the following image series Armstrong in frontal view (and in motion) is a good vertical reference. The derived vertical direction looks perfect; it is not influenced by his bearing, i.e. whether he is fully upright or leaning forward. If one looks at the video then the good horizontal alignment gets even more evident.

<table>
<tr><td>right: original

below:
100 mrad rotated to the left (5.7°)

bottom:
200 mrad rotated to the left (11.5°)</td><td></td><td>below:
100 mrad rotated to the right (5.7°)

bottom:
200 mrad rotated to the right (11.5°)</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td></td></tr>
</table>

Picture 3

Already in the image with a left rotation of 100mrad Armstrong looks unrealistically tilted. The reality should therefore be in the range of ±100mrad; according to my opinion close to the original.
For this reason I will have a closer look to the original and the 100mrad left rotated images.
In the 100mrad right rotated image the „Looking down to the sky" effect is even more obvious than in the original, and the 200mrad rotated images remain out of consideration due to the obviously tilted astronauts.

For a better analysis of these images the position of the camera is considered. The camera is mounted on the MESA (Modular Equipment Storage Assembly), as shown in the training picture on the right.
The distance to the camera is estimated to 2-3m. I will calculate with 3m in the following. The 3m correspond well with the lunar map, where the distance between the feet of the LM is 6m. The camera is approximately in the middle.

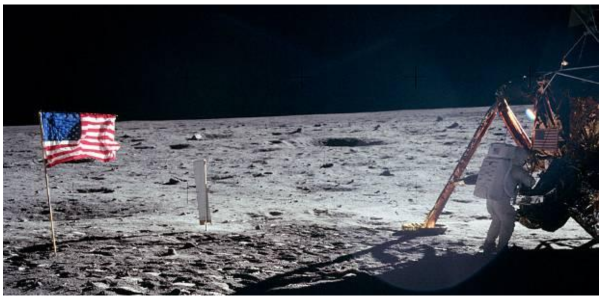
from ap11-S69-31584

Picture 4 Ladder and camera

The height of the camera can be estimated from Picture 5: it is about on the height of the chest of Armstrong, thus about at 1.3m.
The MESA is here covered with isolation foil, and only the camera lens is visible. Such a foil was used for the flight of Apollo 11. Also today’s satellites are covered with such foils (multilayer insulation foils).
The constellation is representative for the situation on the Moon, as it can be seen on Picture 6.

S69-31060b

Picture 5 Armstrong at the MESA



part of AS11-40-5886

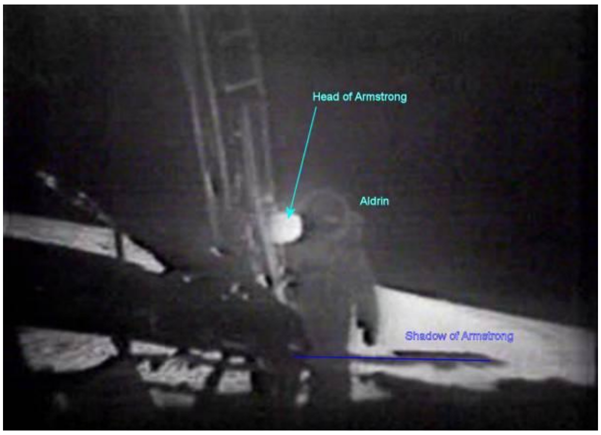
Picture 6 Armstrong at the MESA

I have assumed the camera height in the video images about at the height of the head, thus higher than in the training pictures. Therefore the camera height will be further investigated in the following.
In Picture 7, where Aldrin is leaning slightly forward, one looks from above on his helmet and his knapsack, and in Picture 8, where he is upright, just to the upper edge of the knapsack. For the camera height there results about 1.80m, what corresponds to the body height of Aldrin or Armstrong respectively.

Picture 7 Still Image from the Live Video

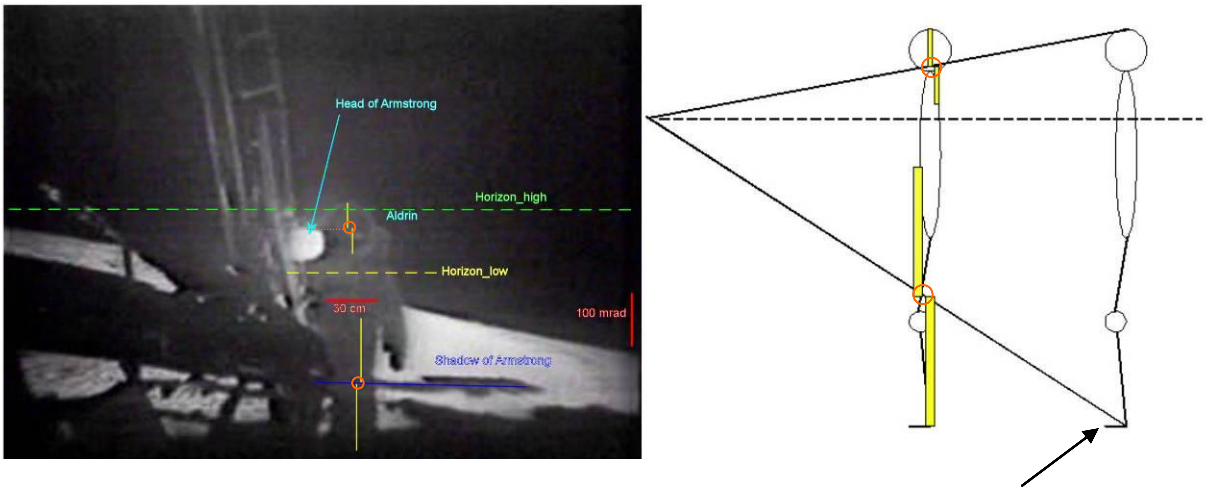
Picture 8 Still Image from the Live Video

For a more detailed analysis Picture 9 is used. Behind Aldrin one can see the head of Armstrong and his shadow (labelled). With help of this image the camera position shall be investigated again: Armstrongs feet are vertically below his head and in the extension of his shadow, which I have indicated with a blue line. It is not clearly known whether Armstrong is fully upright. If not his head could be a bit higher if he were fully upright, i.e. his head could be on the same height as the head of Aldrin. This would fit with my initial assumption of a high horizon on the height of Aldrins head.



Picture 9 Still image of the Live Video

If both heads were on the same height they would be on the same horizontal line together with the camera. This is assumed here as an upper limit of the camera height.
To get an estimation of a possible lower limit of the camera height let us assume that Armstrong is also upright (what is unlikely). Since his head is visible below Aldrins head the camera ought then to be on a lower height. The sketch on the right in Picture 10 shows the constellation and how the height of the camera can be reconstructed with the theorem on intersecting lines. There are vertical yellow bars on the sketch (length: from the border to the intersection) ; 2.4 short bars are needed to reach the camera height from the top and 2.4 long bars to reach it from the bottom. The position of the feet is extrapolated. The length of the bars in the image was determined relative to the body height. Only the full bars are shown, the two 40%-bars have to be imagined in the middle. The resulting camera height is finally indicated with the yellow dashed line with the label Horizon_low. I have neglected perspective contractions. This method gives the lower end of the possible horizon because a fully upright Armstrong has been assumed. The resulting low horizon is on the height of the chest of Aldrin at about 1.4m. This fits well with the height according to the training picture (1.3m).



Picture 10 Still image from the Live Video and Sketch, assuming Armstrong upright

There are now two constellations for further investigations:
(1) mathematical horizon[1] or camera height at approximate 1.8m (head) or
(2) at 1.4m (chest).
The tilt of the picture (roll angle) is well adjusted. The influence of a 100mrad tilt will be investigated later in this section.

Let us have a closer look to the two constellations:
(1) Horizon high (at the height of Aldrins head, at approx. 1.8m):
Here the border of the site fits well to a flat area (soccer field). It would also fit if both the border line and the platform were slightly inclined in either direction. The whole area is below the mathematical horizon.
Both lines, the border and the horizon, meet in the vanishing point.
The "Looking down to the sky"-effect is extraordinary large.

(2) Horizon low (at the height of Aldrins chest, at approx. 1.4m)
Here the left part of the terrain is higher and the right part lower than the mathematical horizon. This would fit to a significantly inclined terrain, which has neither been observed on the colour photos nor on the video, specifically not on the sequence around the flag (Picture 29 and Picture 30). But more important is that the "Looking down to the sky"-effect is still obvious on the right side.

How big is the down-slope of the line-of-sight?
Since the constellation is known the picture can be scaled: a 1:10 angle (= 100mrad or 5.7°) corresponds to a length of 30cm at Aldrin, calculating with a distance of 3 m from the camera to Aldrin (see above). Such a 30cm-ruler is indicated as a red line at Aldrin and also as a vertical line to demonstrate the down-sloping of the line of sight. The vertical line is labelled with "100 mrad" and has the same length as the 30cm-ruler.
For both cases a 1:10 down slope of the line of sight to the sky or even larger can be observed. This would still be the case even if the camera or horizon were set to 1.3m, i.e. to the estimated height of the camera according to the training picture (Picture 5).
If one assumes the low mathematical horizon of 1.3 m and an additional image tilt of 100mrad there still results a „Looking down to the sky" effect of more than 50 mrad.
In the paper the result was also 50mrad, calculated as „height_of_the_camera : distance_to_the _horizon = 1.5m:30m.

[1] Mathematical horizon = Intersecting line of the celestial sphere with a horizontal plane containing the position of the observer (here: position of the camera)

Picture 11 Still image from the live video[2]

Picture 12 100mrad rotated to the left

It may be astonishing that the resulting down-slope of the line of sight is even larger than 1:10. One possible reason is the margin which has been applied for the colour photos.
My subjective estimation of the horizon is case (1), i.e. the high horizon. I may be right for one of the following two reasons:

1. The MESA and therefore the camera on the “real” LM, i.e. the one which has been used for the video, are higher compared to the one on the training picture.
2. For the video just another camera position has been used, i.e. a position above the nominal camera location.

Conclusion

After this detailed analysis of the video pictures with Aldrin at the ladder a “Looking down to the sky”-effect of more than 1:10 is present for all possible camera heights. This clearly demonstrates that this video must have been shot in a studio.
Just as a reminder: a “Looking down to the sky” of 1:10 is huge. It would only be possible on a 8600m high platform – with no visible mountains in the neighbourhood of 170 km. This result is even clearer than the one in the paper, where ample margin was applied. The result was there a down-slope of 1.5:30, which led to a 2100 m high mountain with no visible neighbours in the next 87km. This result is achieved here if the still image is additionally rotated by 100mrad.
A possible inclination of the terrain is not relevant any more with this method of direct angle measurement.

Since the video is reported to have been sent live, there was no opportunity for on-line corrections. In 1969 there were no computers which could have eliminated the background during the transmission.

[2] According to the camera manual (http://history.nasa.gov/alsj/a11/a11TVManual.pdf) the TV camera can be used with different lenses. If one calculates according to the 30cm ruler in Picture 11 the diagonal field angle, so 13.8·100mrad = 79° result. This is in a very good accordance with the wide angle lens with a diagonal field angle of 80°. The next smaller, the Lunar Day Lens, has a diagonal of 35°. The wide angle lens was foreseen for scenes within the spacecraft. On the lunar surface its use was limited to scenes of indirect solar illumination.

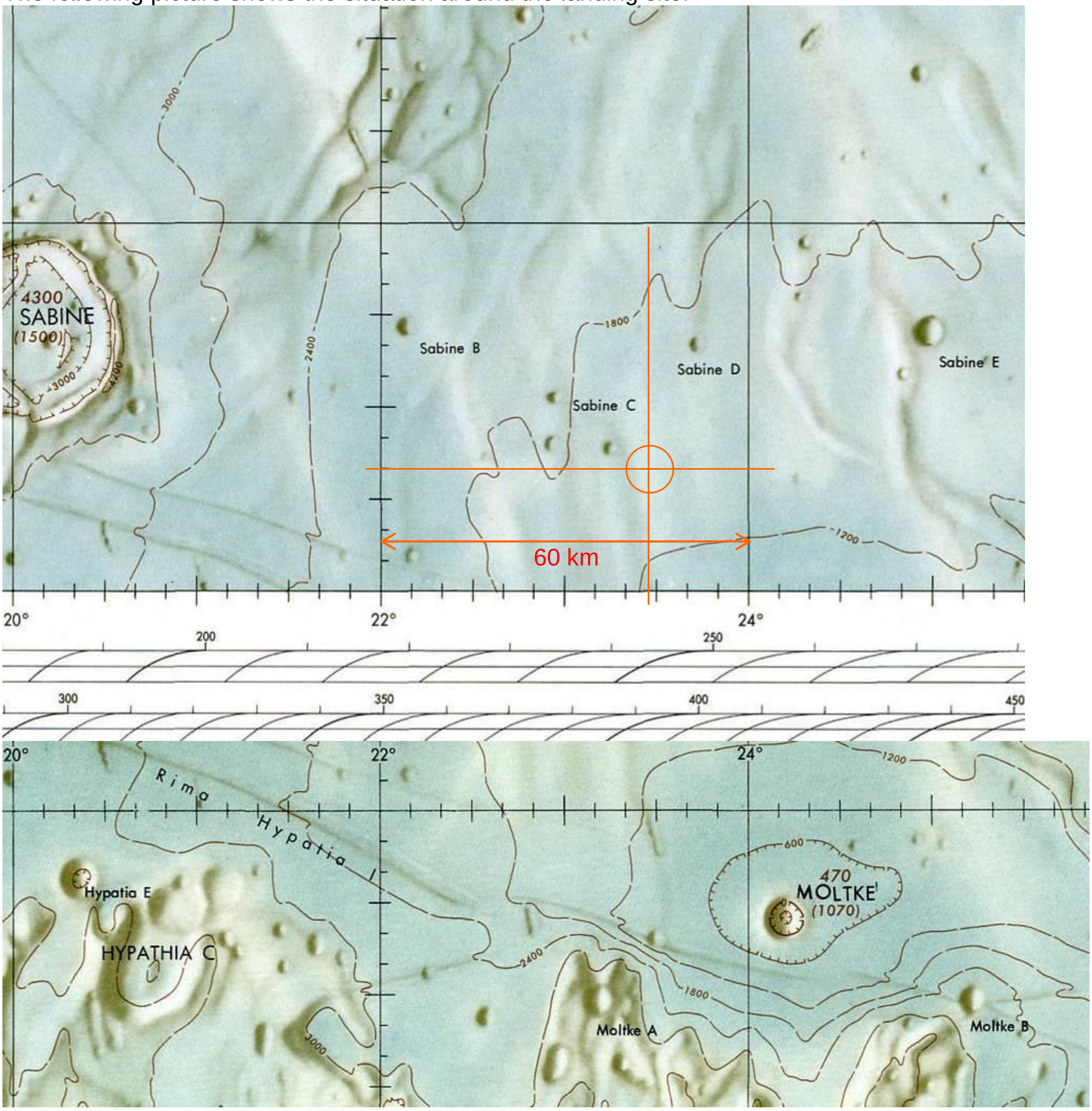
3 Maps

Looking downwards directly into deep space might only be possible if the terrain were strongly descending. Looking to a map one recognises that in the contrary the terrain is sloping upwards on the west side (indeed in the whole western semi-circle, i.e. from N over W to S) in the order of 10 to 20m per km. Since the landing took place in a lunar morning the shadow direction is approximately west.

Good maps can be found under http://www.lpi.usra.edu/resources/mapcatalog/LAC/. The landing site of Apollo 11 (0.67°N, 23.47°E) can be found on the map "LAC-60 Julius Caesar"

The equidistance between the level curves is 600m; the altitudes are given in meters.

The following picture shows the situation around the landing site:

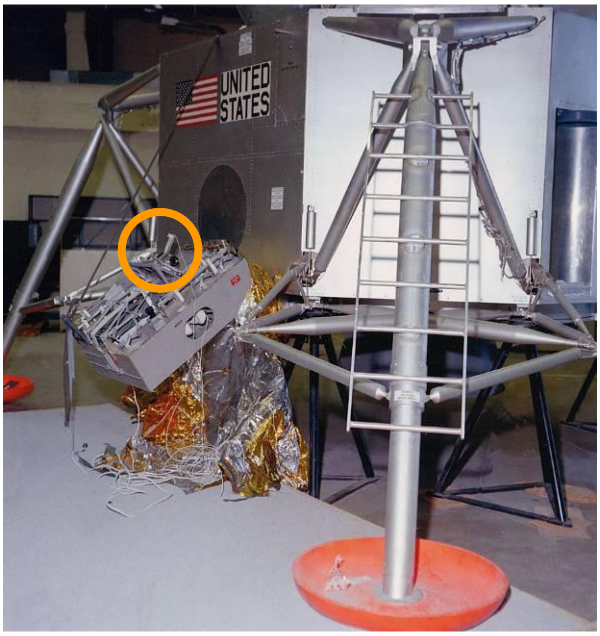


Picture 13 Environment of the Apollo 11 landing site

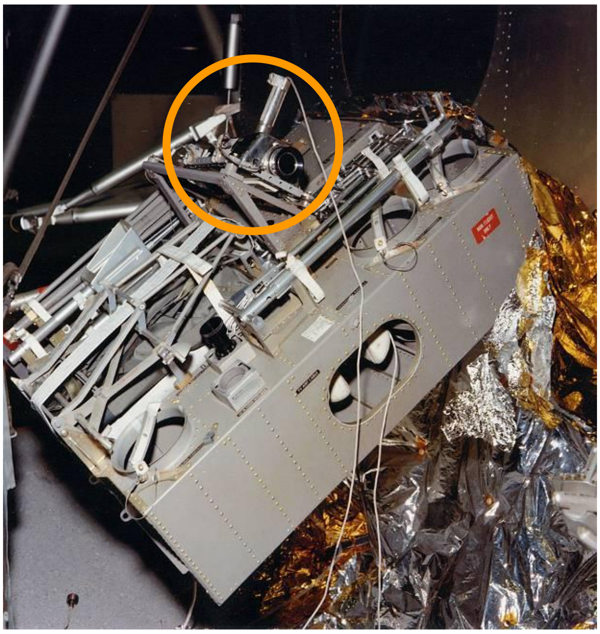
To exclude such a "Looking down to the sky"-effects from being reality on the Moon, these maps are more than sufficient.

4 Tilted Camera

In the context of the camera position it was noticed that the camera is mounted on the MESA with a tilt, as one can see on the following two pictures:



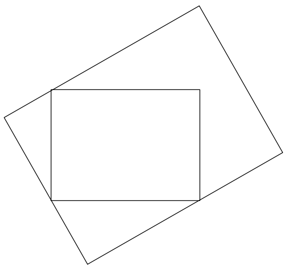
ap11-S69-31585
Picture 14



ap11-S69-31584
http://history.nasa.gov/alsj/a11/ap11-S69-31584.jpg
Picture 15

The camera is according to the training Picture 15 tilted by estimated 30° to 45°.
In http://www.history.nasa.gov/alsj/a11/images11.html#Mag40 one can read *"The camera was mounted on the MESA upside down ... It was placed at an angle so that the bottom of the ladder could be viewed when the MESA was fully deployed*". This means the above mentioned tilt was intended to utilise the maximum diagonal field angle down to the bottom of the ladder, and that the training pictures are therefore well representative.
NASA had the capability to invert the pictures, as it can be found under http://history.nasa.gov/alsj/a11/a11.step.html : "*Each of the tracking stations had the capability of inverting the image so it would look normal. This was done by throwing a switch from the 'normal' position - used when the camera was on its tripod away from the LM and was, therefore, rightside up - to the 'inverted' position - used when the camera was upside down on the MESA.*"

But nothing is mentioned about rotating a picture. At a rotation of a 4:3 TV image e.g. by shooting it from a TV screen a big part of the original image would be lost, as one can see on the sketch on the right.
Both images, the original one and the new one have a width-to-height ratio of 4:3. However the image shows the full field of the wide angle lens.
The original image is 30° tilted.



Picture 16

A rotational image correction is very unlikely due to the image loss. So in 1969 the "live video" should have looked as shown in the attached picture series, with the bottom of the ladder close to the left corner.
I have rotated the Picture 3 by 30° on a black background.

Left: View from the tilted TV camera
Middle: Same picture, as it should have appeared on a television set (just rotated)
Right: Official still image from the live video
(The left and the middle picture were established from the original one on the right.)

Picture 17 Demonstration of the (not) tilted TV images

This contradiction is a nice extra goody, but not necessary to demonstrate the Looking-down-to-the-sky effect.

The so called live video has therefore not been shot from the official camera position. Neither the tilt nor the height of the camera, which have been estimated from the photos, correspond with the official documentation. This contradiction is not a proof for studio pictures, because the documentation could just be wrong. May be the camera could have been mounted horizontally aligned. But at another location of the documentation the tilt of the camera is taken to explain the tilted horizon: In the "Apollo 11 Lunar Surface Journal" http://history.nasa.gov/alsj/a11/a11.step.html one can read *"that the lunar horizon is tilted down to the right by about 11 degrees because the TV camera is tilted by about that much inward toward the spacecraft, as can be seen in pre-flight photo S69-31585"* (here: Picture 14). According to this the tilted camera had made a tilted photo of the effectively horizontal horizon, what is the case at a tilted camera, but "forgotten" to tilt also the astronaut ...

5 Arguments in the Context with the Colour Photos

In this chapter there is supplementary information to the paper, specifically where not everything is traceable or where additional considerations have been made in the meantime. Furthermore the horizontal alignment of the pictures is estimated, similar to the video case.

5.1 Calculation of the Sun Incident Angle and the Length of the LM's shadow

The calculation of the sun incident angle is not totally precisely described in the paper. Here is the exact procedure: I selected the picture with the solar wind collector, where I estimated the influence of the perspective contraction being small.
I measured its height and the length of its shadow directly on the picture and calculated the sun inclination angle as arctan(height/shadow_length)=21°. With this I calculated the length of the shadow of the LM as (height of the LM)/tan(21°)=6.5m/tan(21°)=17m. To this result I added a margin.

AS11-40-5872
Picture 18 Image with the solar wind collector

<u>Check of the sun incident angle according to the ephemerides:</u>
In the meantime I have checked the sun angle on the following web page http://www.mondlandung.pcdl.de/ (-> Mondphasen) where the phase of the Moon is indicated. The distance to the day-night-border (=sun incident angle) was at landing approx. 10° and at launch 25°. For the photo (taken 7 hours after landing) an angle of 10°+(25°-10°)*7h/22h =15° or 1:3.7 results. With such a 15° sun inclination[3] the shadow of the LM becomes 6.5m/tan(15°) = 24m or 40% longer compared to my initial estimation.
In the paper the inclination of the line-of-sight resulted to 1.5m:100m, i.e. the additional 40% of the length of the shadow are more than covered by this calculation.

For the picture on the right I would rather calculate with a distance to the horizon of 50m. These 50m are composed as follows:

Camera to LM:	10m (estimated[4])
LM to border:	24m (length of the shadow)
Margin:	16m
<u>Camera to border:</u>	<u>50m</u>

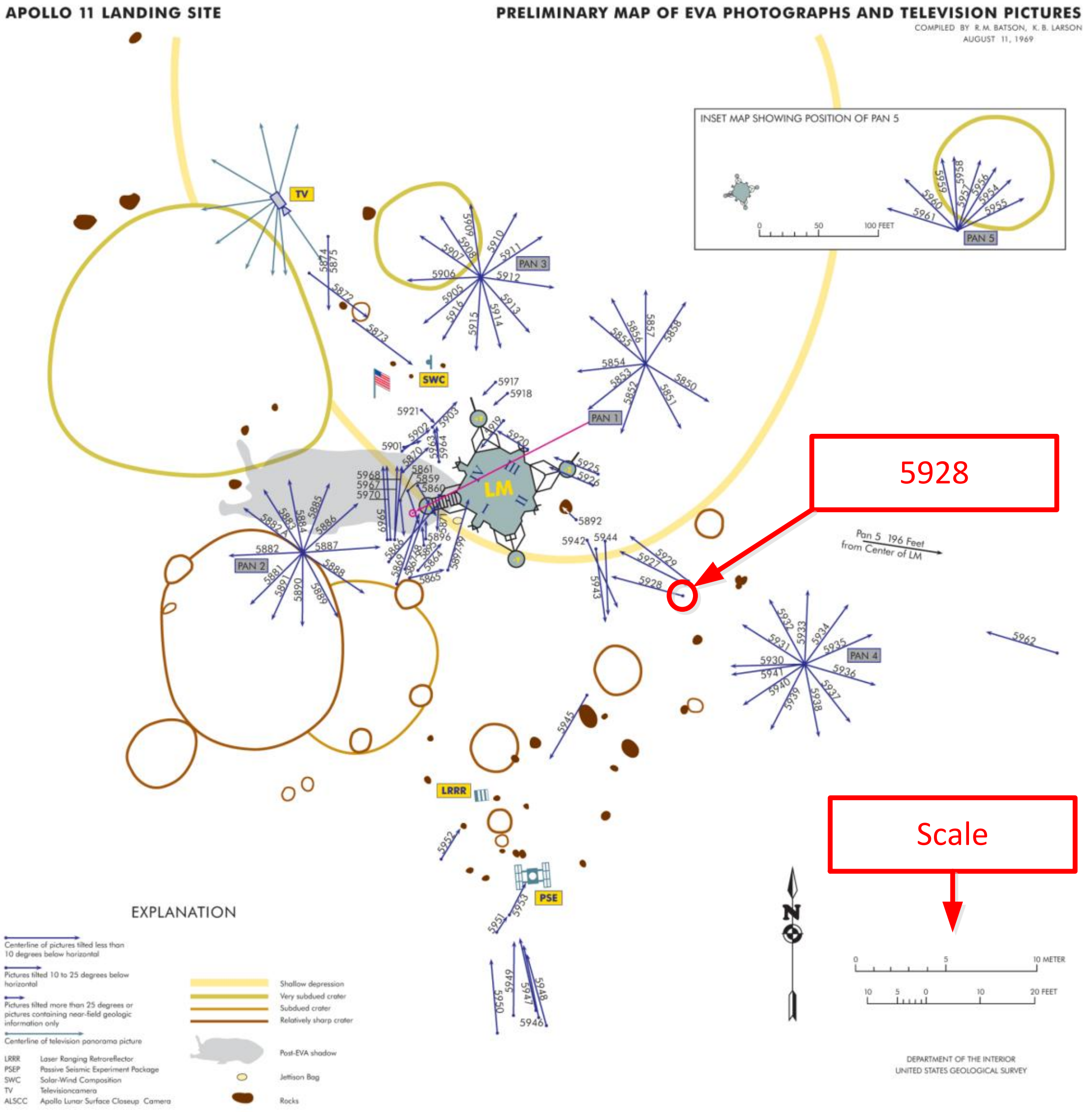
AS11-40-5928
Picture 19

[3] 15° also fits with the NASA data in http://www.hq.nasa.gov/alsj/alsj-sunangles.html: 14.0°-15.4°
[4] If one uses the distance of the crosshairs of 10.3° (http://history.nasa.gov/alsj/alsj-reseau.html) and measures the length of the astronaut (about 1.8m) to 1.14 times the crosshair distance, so a distance of the camera of semi_astronaut_length:tan(1.14·10.3°/2) = 0.9m:tan(5.87°) = 8.8m results. This corresponds well with the above estimated 10m.

I made all calculations for a flat (horizontal) terrain. If the terrain were sloping up in the direction of the critical border of the ridge (the worse case for the “looking down to the sky”-effect) then the shadow would be shorter, so I had not to add extra margin.

5.2 Comparison with the Photogrammetric Analysis of NASA

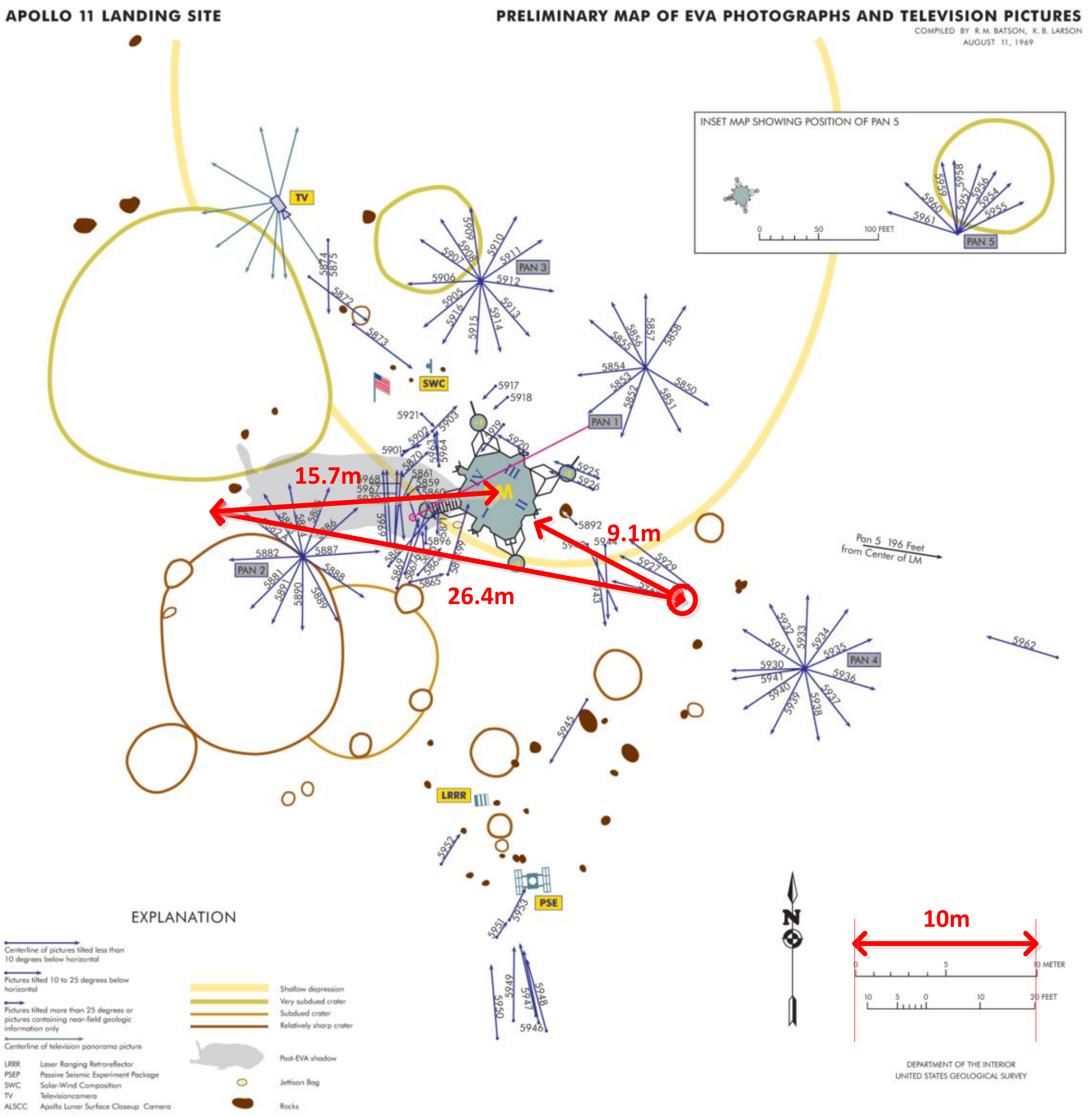
NASA did a photogrammetric investigation of the photos of the Apollo 11 Landing site [http://www.hq.nasa.gov/alsj/a11/a11Photogrammetry.html] and set up a map with the location and the viewing direction of the camera [http://www.hq.nasa.gov/alsj/a11/a11photomap.gif]:



Picture 20 Map with Camera Positions and Directions

I have marked the camera location for the photo AS11-40-5928 red and I have highlighted the scale in red as well.
NASA writes that contrary to what is shown in the preliminary map, the three images 5927, 28 and 29 were shot from the same location, all within ~10 cm of each other. For the following investigation this is not of importance.

According to the above map the up to now estimated distances can be checked. On the following picture these distances are sketched in red:



Picture 21 Relevant Distances to the Photo AS11-40-5928

As you can see the distance from the camera to Aldrin corresponds well with my result. The length of the shadow and therefore also the distance from the camera to the tip of the shadow is here clearly smaller.
This NASA analysis confirms that the up to now presented numbers are – as intended – on the conservative side.

5.3 How well is the Camera Adjusted; Horizontal and Vertical References

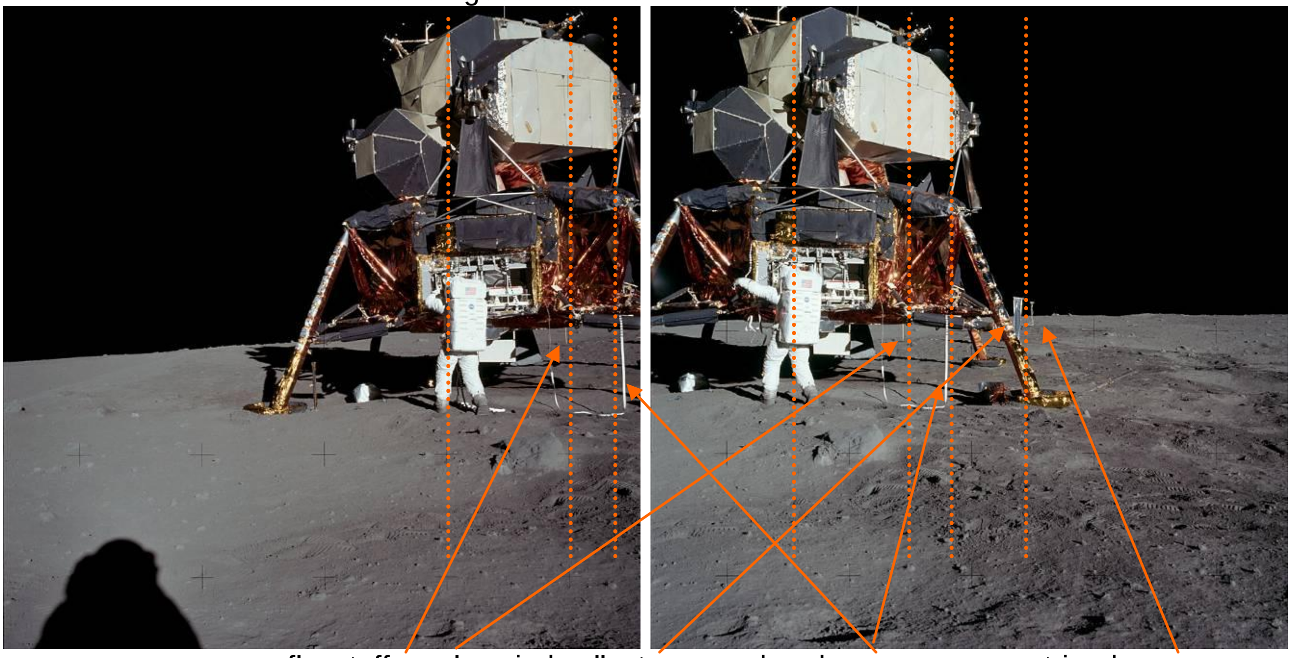
Under a well horizontally adjusted camera I understand that it is not tilted, i.e. that the upper and lower image border are horizontal. However the mean camera direction may slope upwards or downwards.
This is the case for most of the photos in general.

The „Looking down to the sky“ effect is obvious if one assumes that the images are well horizontally aligned. Therefore one would have to rotate the images to convert them into (horizontally well aligned) pictures possibly originating from the Moon. This is why often the objection was made that the images were badly horizontally aligned and that it were impossible to draw a horizontal line. Because this is a vital point in the argumentation, it is investigated in detail. With this chapter it should be demonstrated that also the colour photos were made with a very high probability in a studio.

The camera is mounted on the space suit. So the pictures should be well horizontally aligned.

ap11-S69-31109
Picture 22

In the images there are different references which confirm that the camera is not or only slightly tilted: flagstaff, solar wind collector and tripod look vertical from all viewing directions; in addition the astronauts are often good indications for the vertical.



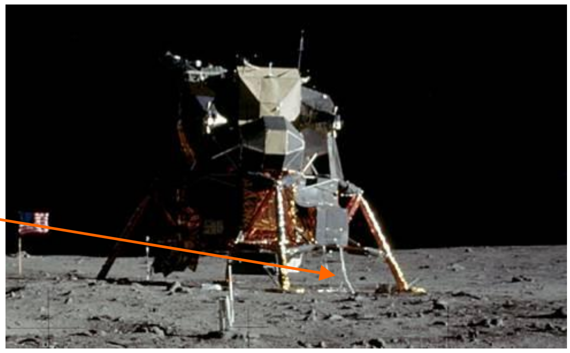
flagstaff solar wind collector band tripod

AS11-40-5928 and 5929
Picture 23

According to the dotted vertical lines one sees on the above pictures that both images are well horizontally aligned. In particular in the right image the band, which is hanging down, is a perfect vertical reference because it appears as a straight line.

From another direction one can see that the band is not fully vertical and that it touches the ground; but there it has a shape of a catenary curve.

band



Part of AS11-40-5948
Picture 24

To distinguish between “well” and “badly horizontally aligned” one can give tolerances, e.g. as follows:
In a well horizontally aligned image the accuracy of the vertical direction is better than $\pm$50mrad. To be totally sure, one can calculate with $\pm$100mrad.

To demonstrate the effect of a 50mrad (2.9°) or 100 mrad (5.7°) tilt, the following image series is shown. In these images there are trees and candelabra which form good vertical references.

A 50mrad tilt strikes out only if there are good references, i.e. objects with a long vertical base. A 100mrad tilt seems rapidly unrealistic for upright humans.

right: original with vertical trees and candelabra

below:
50 mrad rotated to the left (2.9°)

bottom:
100 mrad rotated to the left (5.7°)

below:
50 mrad rotated to the right (2.9°)

bottom:
100 mrad rotated to the right (5.7°)

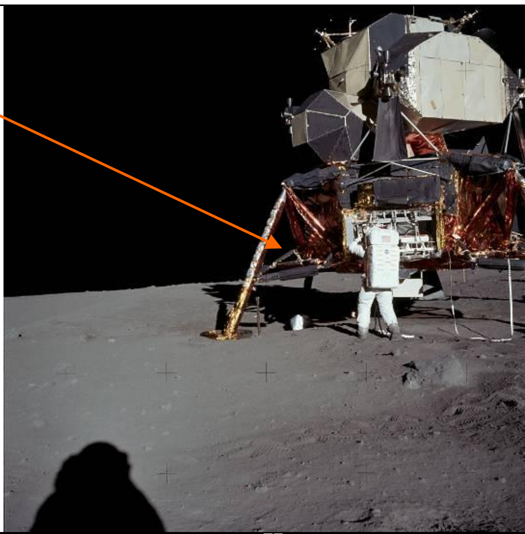
Picture 25

As a comparison I select the „suspicious“ image with the most evident „Looking down to the sky“ effect (AS11-40-5928). I drew vertical lines and a possible horizon (on the height of the camera). Due to the band on the right I think the exact horizontal alignment is between the original and the image rotated 50mrad to the right.

right: original,
rear strut

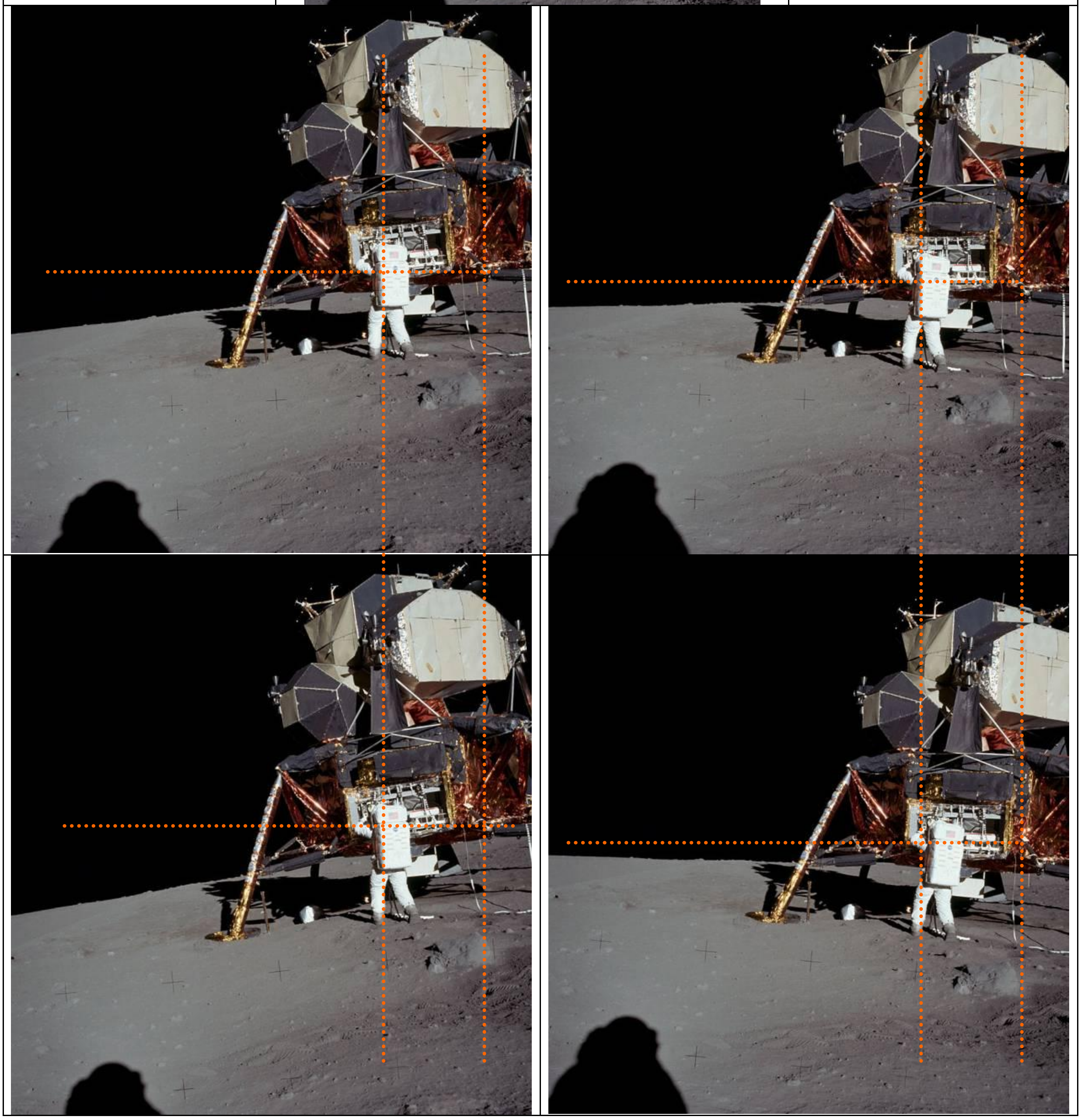
below:
50 mrad rotated to the
left (2.9°)

bottom:
100 mrad rotated to
the left (5.7°)



below:
50 mrad rotated to the
right (2.9°)

bottom:
100 mrad rotated to the
right (5.7°)



Picture 26

The astronaut does not look vertical any more on the two images on the bottom. The „Looking down to the sky“ effect is visible in all images: one looks from the top on the rear strut and from there directly to the „sky“. The LM should have to be very strongly canted towards the camera, in order that the line-of-sight were sloping up. But this does not correspond with the image with the flag (Picture 27), where the terrain looks flat or almost flat.

All this seems to be (almost) proof enough, but opponents of the studio thesis state, besides the argument that the horizontal and vertical were not exact,

- the terrain were significantly inclined
- the camera height were lower than assumed by me

Both of these arguments are in contradiction to the view to the rear strut: were the camera low (lower than the horizon), the LM would almost have to cant over. The terrain could slightly be inclined, but, as just described, one looks down to the horizon in all cases.

The margin is rather small for these images. That is why I had looked for further information and had found the video, where the circumstances are very clear, as described above, and where the contradiction with the tilted camera appeared.

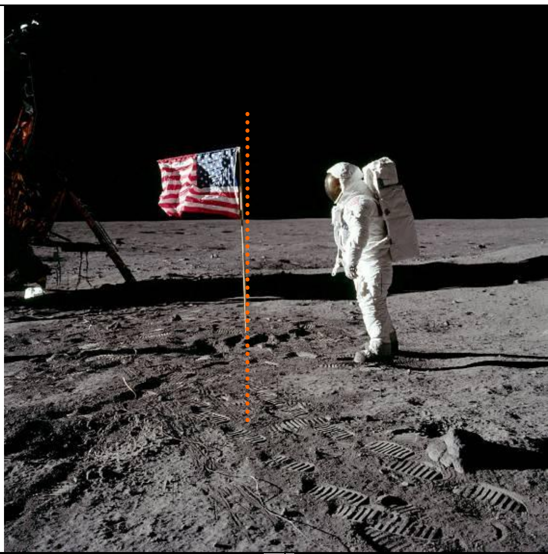
For the sake of completeness I finish this chapter with the analysis of the photo with the flag:

right: original (AS11-40-5875)

below:
50 mrad rotated to the left (2.9°)

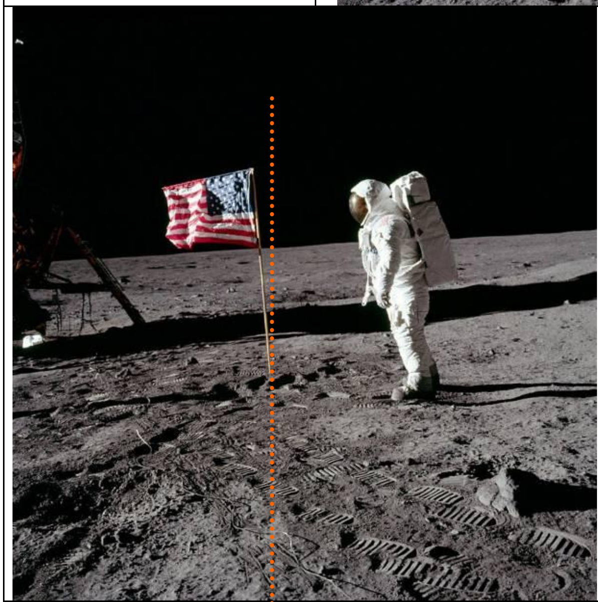
bottom:
100 mrad rotated to the left (5.7°)

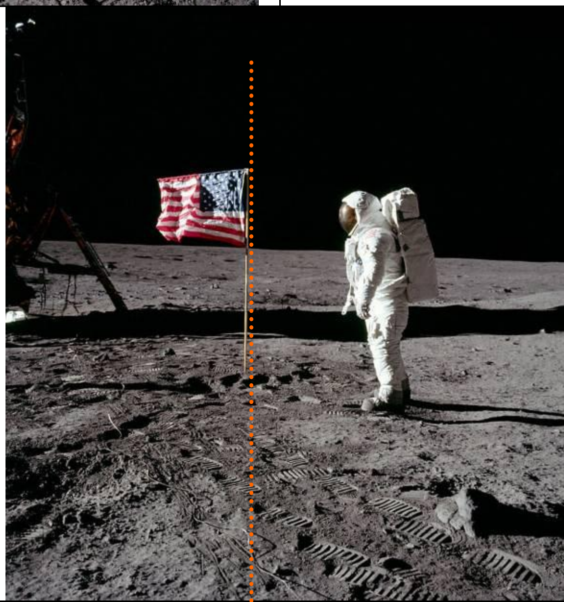
Aldrin seems to cant over.

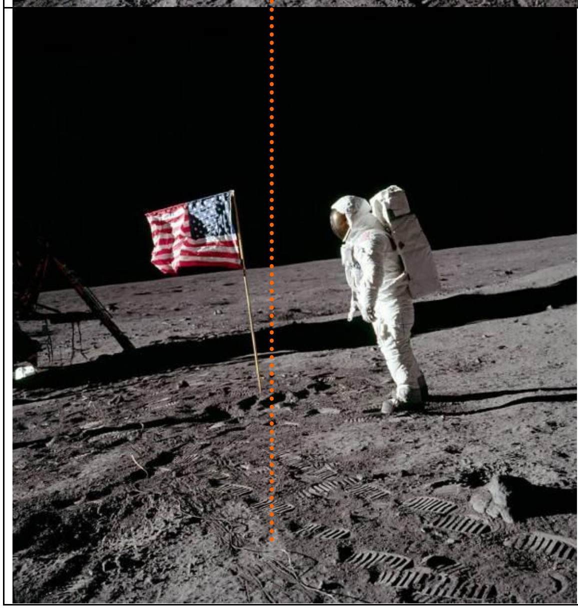


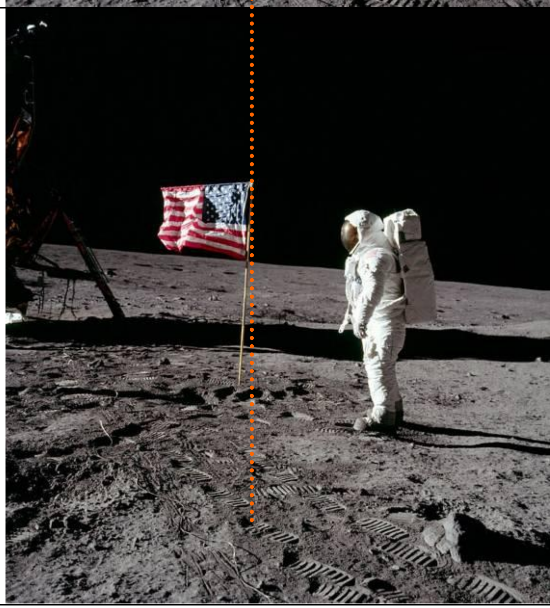
below:
50 mrad rotated to the right (2.9°)

bottom:
100 mrad rotated to the right (5.7°)









Picture 27

6 Flatness of the Landing Scenery according to a further Video (with the Flag)

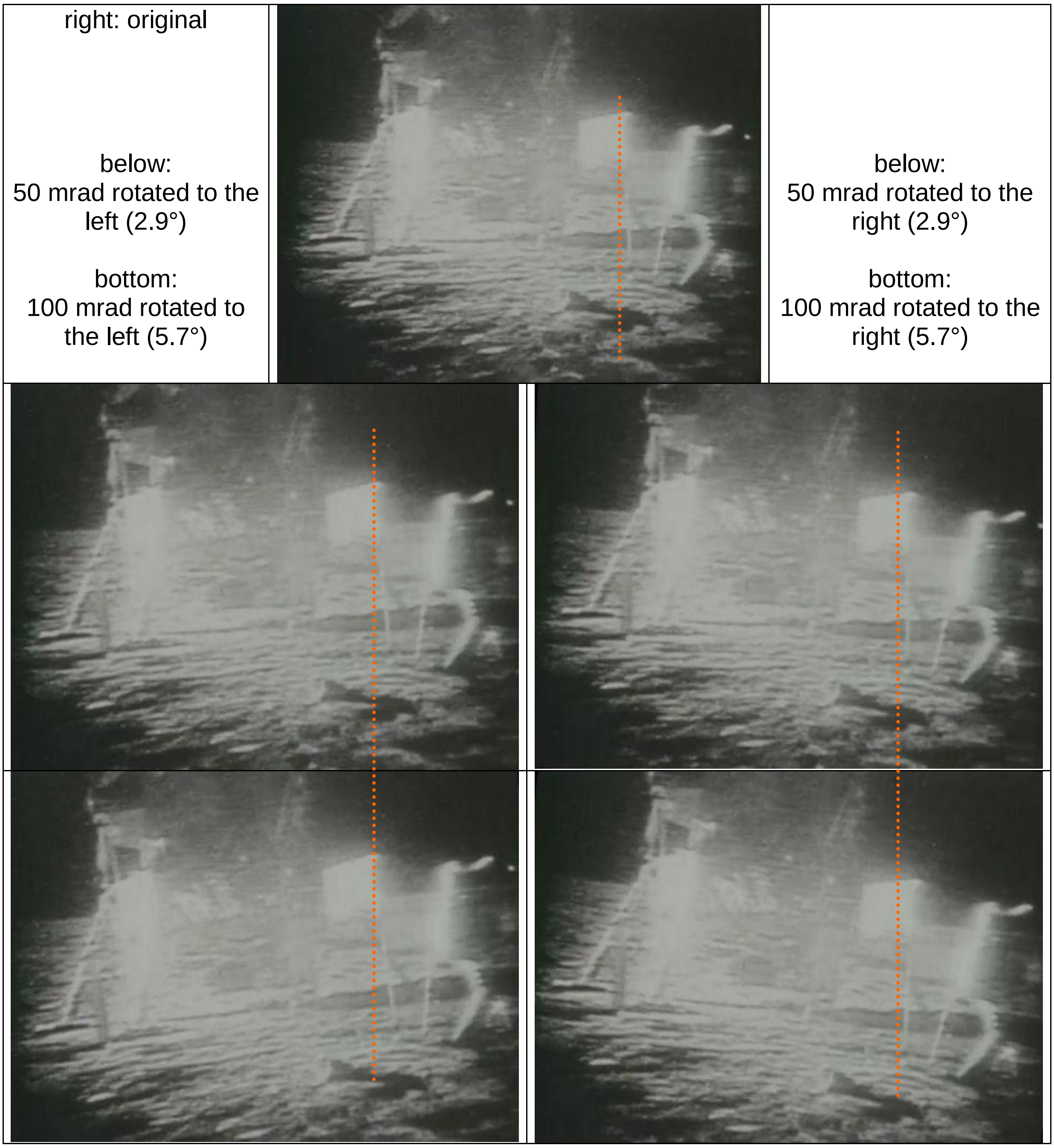
In the still images of the videos the „Looking down to the sky“ effect is even more obvious compared to the colour photos, so that the video is sufficient to proof the studio thesis.

Opponents of the studio thesis hardly argued concerning the videos. The horizontal alignment of the camera has been challenged and also the assumed camera height. But in consideration of the clarity of the „Looking down to the sky“ effect nobody has given concrete arguments, i.e. has shown how one possibly had to rotate the still image to see a real lunar landscape; and on which height the camera should be.

The videos demonstrate even more clearly than the colour photos that the terrain is flat and level. Specifically in the scene with the flag, where astronauts are passing by, the flatness can be estimated very well, particularly perpendicular to the direction of observation. This direction corresponds approximately to the direction of the camera in the previous chapter.

The following two image series show that the terrain around the LM is flat (horizontal). I estimate that the inclination is less than 1° (17mrad). Applying margin one could calculate with 50mrad. For clarification: roads with an inclination greater 100mrad are specifically marked with a slope warning sign. But as shown in a previous chapter the inclination of the terrain was not relevant any more in case of the video images.

Picture 28



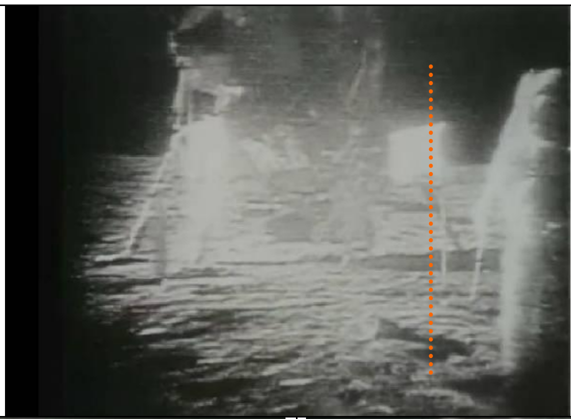
Picture 29

Since the astronaut on the right is seen from the side, I show another series where he is bouncing towards the camera and therefore a better vertical reference. The best impression is achieved by looking the video.

right: Original

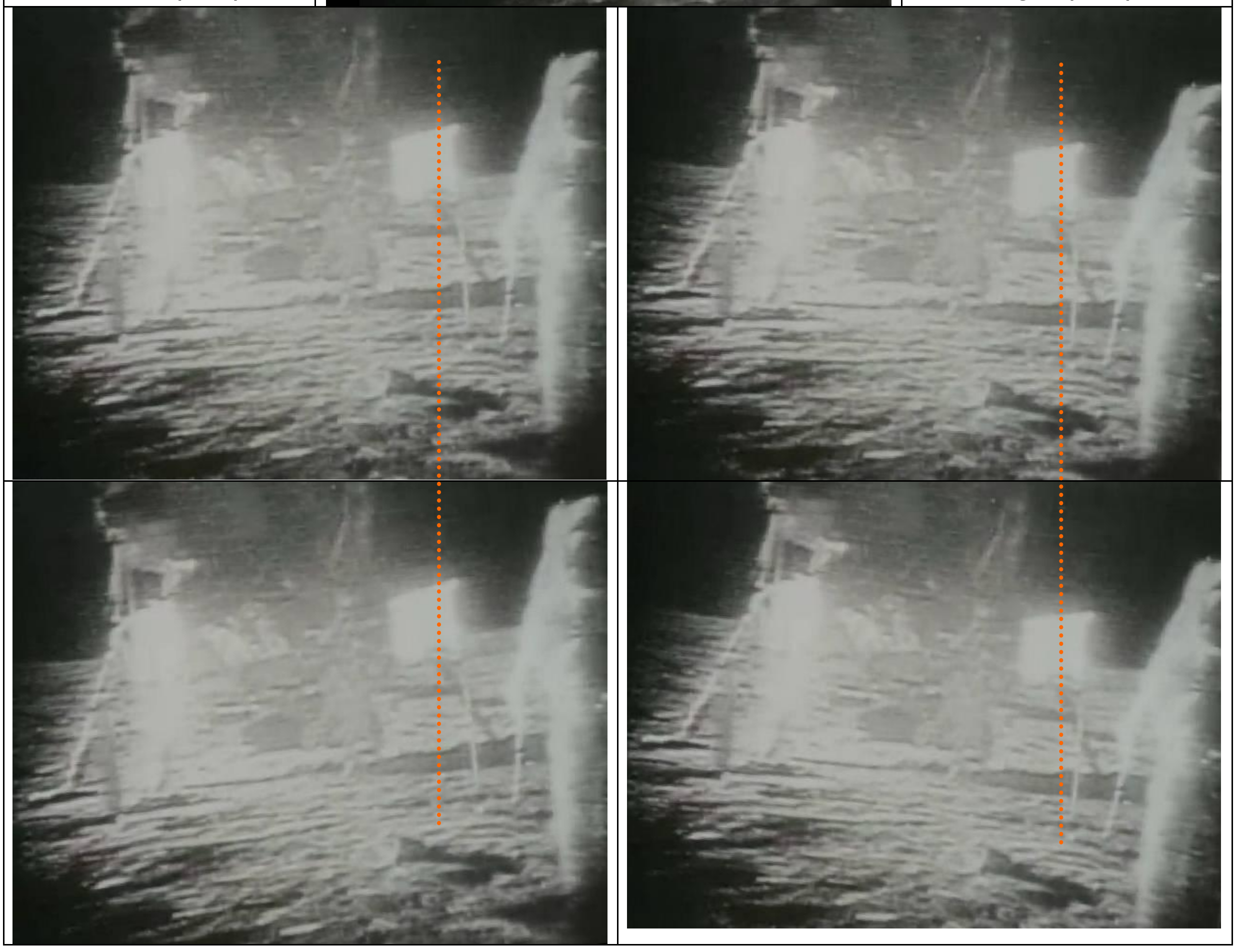
below:
50 mrad rotated to the left (2.9°)

bottom:
100 mrad rotated to the left (5.7°)



below:
50 mrad rotated to the right (2.9°)

bottom:
100 mrad rotated to the right (5.7°)



Picture 30

The reality should be in the range ±50mrad. At ±100mrad the tilt is obvious. Watching the videos the tilt looks good, i.e. one has never the impression of a tilted camera.

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