LUVOIR-A vs LUVOIR-B considerations for exoEarths & solar system
ExoEarth candidate yields (courtesy of Chris)

<table>
<thead>
<tr>
<th></th>
<th>LUVOIR-A</th>
<th>Un-Descoped LUVOIR-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>exoEarth candidate yield</td>
<td>$51^{+75}_{-33}$</td>
<td>~25</td>
</tr>
<tr>
<td>Circumscribed diameter (m)</td>
<td>15.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Inscribed diameter (m)</td>
<td>13.5</td>
<td>6.7</td>
</tr>
<tr>
<td>IWA</td>
<td>$3.8 \lambda/D$</td>
<td>$2.4 \lambda/D$</td>
</tr>
<tr>
<td></td>
<td>$31.9$ mas = 0.319 AU @ 10 pc</td>
<td>$40.6$ mas = 0.406 AU @ 10 pc</td>
</tr>
</tbody>
</table>

Yields are for a 2 years out of a 5 year prime mission in both cases
ExoEarth candidate yields (courtesy of Chris)

<table>
<thead>
<tr>
<th></th>
<th>LUVOIR-A</th>
<th>Un-Descoped LUVOIR-B</th>
<th>HabEx</th>
</tr>
</thead>
<tbody>
<tr>
<td>exoEarth candidate yield</td>
<td>$51^{+75}_{-33}$</td>
<td>~25</td>
<td>12</td>
</tr>
<tr>
<td>Circumscribed diameter (m)</td>
<td>15.0</td>
<td>8.0</td>
<td>4</td>
</tr>
<tr>
<td>Inscribed diameter (m)</td>
<td>13.5</td>
<td>6.7</td>
<td>4</td>
</tr>
</tbody>
</table>

LUVOIR yields are for a 2 year program (imaging, orbits, partial spectra)
HabEx yield for a ~3.75 year program (imaging, orbits, complete spectra)
What does 25 exoEarth candidates tell us?

- Required number of habitable planet candidates:
  - LUVOIR-A: 51 candidates
  - LUVOIR-B: 25 candidates
  - HabEx-A: 12 candidates
  - Exo-S?: 2 candidates

- 25 candidates can constrain the frequency of planets with water vapor to 11.5% with 95% confidence.

Percentage of candidates with water:
- 5.9%
- 11.5%
- 23.5%
- 87.2%
Table 14.2. Summary of adopted coronagraph performance. Listed contrast is for a theoretical point source; contrasts used in simulations included the effects of finite stellar diameter. While only the spatially averaged raw contrast and coronagraph throughput are indicated, AYO simulations used their actual values at the planet angular separation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>APLC₁</th>
<th>APLC₂</th>
<th>APLC₃</th>
<th>VC</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\zeta$</td>
<td>$4 \times 10^{-11}$</td>
<td>$5 \times 10^{-11}$</td>
<td>$5 \times 10^{-11}$</td>
<td>$3 \times 10^{-10}$</td>
<td>Raw contrast(^a)</td>
</tr>
<tr>
<td>$\Delta \text{mag}_{\text{floor}}$</td>
<td>26.5</td>
<td>26.5</td>
<td>26.5</td>
<td>26.5</td>
<td>Systematic noise floor (faintest detectable point source)</td>
</tr>
<tr>
<td>$T_{\text{core}}$</td>
<td>0.19</td>
<td>0.26</td>
<td>0.26</td>
<td>0.17</td>
<td>Coronagraphic core throughput(^a)</td>
</tr>
<tr>
<td>$T$</td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td>End-to-end VIS channel detection throughput (including QE, excluding core throughput)</td>
</tr>
<tr>
<td>IWA</td>
<td>3.8</td>
<td>6.3</td>
<td>11.4</td>
<td>3.7</td>
<td>Inner working angle ($\lambda/D$)(^b)</td>
</tr>
<tr>
<td>OWA</td>
<td>11.5</td>
<td>19.5</td>
<td>33</td>
<td>10</td>
<td>Outer working angle ($\lambda/D$)</td>
</tr>
<tr>
<td>$\Delta \lambda$</td>
<td>10%</td>
<td>15%</td>
<td>15%</td>
<td>20%</td>
<td>Bandwidth</td>
</tr>
</tbody>
</table>

\(^a\)Average value between the IWA and OWA.

\(^b\)Separation at which core throughput reaches half the maximum value.
HabEx Vector Vortex design to approximate LUVOIR-B coronagraph

LUVOIR-B off-axis vector vortex has ~2x throughput and 2x instantaneous bandpass compared to LUVOIR-A APLC
Planet at 5 pc

LUVOIR-A

13.5 m inscribed diameter

20 hours per coronagraph bandpass to get SNR = 10 in visible

Planet Spectrum: Earth

$O_3$

$O_3$

$O_2$

$O_2$

$H_2O$

$H_2O$

$H_2O$

$H_2O$

$CO_2$

$CH_4$
Planet at 5 pc

LUVOIR-A
13.5 m inscribed diameter
20 hours per coronagraph bandpass to get SNR = 10 in visible
10 bandpasses x 20 hours ~ 8 days for full spectrum (APLC)
LUVOIR-B
6.7 m inscribed diameter
45 hours per coronagraph bandpass to get SNR = 10 in visible

Planet at 5 pc

Planet Spectrum: Earth

\[ F_{\text{p}/F_{\text{s}}} \times (\text{g}) \]

**Wavelength [micron]**

- \( O_3 \)
- \( O_3 \)
- \( O_2 \)
- \( H_2O \)
- \( O_2 \)
- \( CO_2 \)
- \( CH_4 \)

**Chemicals Present:**
- Ozone (\( O_3 \))
- Oxygen (\( O_2 \))
- Water (\( H_2O \))
- Methane (\( CH_4 \))
Planet at 5 pc

LUVOIR-B
6.7 m inscribed diameter

45 hours per coronagraph bandpass to get SNR = 10 in visible

5 bandpasses x 45 hours ~ 9.5 days for full spectrum (VVC)
In summary

• Full spectrum w/ LUVOIR-A to SNR = 10 in VIS ~ 8 days
• Full spectrum w/ LUVOIR-B to SNR = 10 in VIS ~ 9.5 days

• So LUVOIR-B + VVC takes ~1.2x as long as LUVOIR-A + APLC to get the same spectrum
Other considerations

• Smaller telescopes have larger IWA. But off-axis vector vortex has a much smaller IWA than APLC (2.4 λ/D vs 3.8 λ/D)
  • VV can even get to as small as ~1.6 λ/D (1% core throughput)
  • This advantage not yet fully captured in characterization plots

• If LUVOIR-A can get spectrum to $\lambda = 2 \, \mu m$, LUVOIR-B can get spectrum to $\lambda \geq 1.57 \, \mu m$

• High exozodi will hurt more for LUVOIR-B
  • Previous simulations assumed EZ = 3 zodis
Planet at 8.5 pc

LUVOIR-A

13.5 m inscribed diameter

61 hours per coronagraph bandpass to get SNR = 10 in visible

IWA (3.8λ/D) cutoff at 2 μm
Planet at 8.5 pc

LUVOIR-B

6.7 m inscribed diameter

178 hours per coronagraph bandpass to get SNR = 10 in visible

IWA (2.4λ/D) cutoff at 1.6 μm
Rotation measurements w/ LUVOIR-B?

LUVOIR-B?

LUVOIR-B

LUVOIR-A

Retrieving Earth’s 24 Hour Rotation Period

<table>
<thead>
<tr>
<th>Rotation Period (hr)</th>
<th>Throughput [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.0</td>
<td>20.44 23.52 23.89 23.95</td>
</tr>
<tr>
<td>15.0</td>
<td>19.36 22.81 23.87 23.96</td>
</tr>
<tr>
<td>10.0</td>
<td>16.83 22.10 23.48 23.92</td>
</tr>
<tr>
<td>7.0</td>
<td>14.52 20.78 23.22 23.74</td>
</tr>
<tr>
<td>5.0</td>
<td>12.46 19.60 22.14 23.25</td>
</tr>
<tr>
<td>3.0</td>
<td>9.64 15.84 20.28 22.24</td>
</tr>
<tr>
<td>1.0</td>
<td>7.84 9.35 12.73 16.40</td>
</tr>
</tbody>
</table>

1σ Uncertainties (hr)

<table>
<thead>
<tr>
<th>Throughput [%]</th>
<th>Diameter [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.0 9.0 12.0 15.0</td>
</tr>
<tr>
<td>20.0</td>
<td>6.74 2.56 1.09 0.21</td>
</tr>
<tr>
<td>15.0</td>
<td>7.66 4.06 1.13 0.23</td>
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<tr>
<td>10.0</td>
<td>8.82 5.05 2.71 0.85</td>
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<tr>
<td>3.0</td>
<td>12.35 9.50 6.91 4.94</td>
</tr>
<tr>
<td>1.0</td>
<td>12.29 13.16 12.17 9.18</td>
</tr>
</tbody>
</table>

But doesn’t take into account increased instantaneous bandpass of LUVOIR-B.

LUVOIR-B might do better.
Solar System - imaging resolution

Pluto

Images by Roser Juanola Parramon
Solar System – imaging resolution

Titan

2.4-m
4-m
8-m
15-m

Images by Roser Juanola Parramon
Solar System – imaging resolution

Neptune

Images by Roser Juanola Parramon
LUVOIR-A vs. LUVOIR-B sensitivity

LUVOIR-A
Collecting area = 155 m$^2$

Un-descoped LUVOIR-B
Collecting area = 43.8 m$^2$

Exposure time ratio
$t_B = 3.54 \times t_A$
Solar System – point source sensitivity

LUVOIR-A HDI
$m_V = 32$, SNR = 5, $t_{\text{exp}} \sim 1.1$ hours

Un-descoped LUVOIR-B HDI
$m_V = 32$, SNR = 5, $t_{\text{exp}} \sim 3.9$ hours
$m_V = 30.6$, SNR = 5, $t_{\text{exp}} \sim 1.1$ hours
Extra slides
Throughput Curves for APLC and VC6

*note: these are outdated curves, but qualitatively show the difference