

```
<?xml version="1.0"?>
```

```
<!-- FILE : LR_II_model_1994.xml
```

```
CREATED : 28th March 2002
```

```
LAST MODIFIED : 30th July 2003
```

```
AUTHOR : Catherine Lloyd  
The Bioengineering Institute  
The University of Auckland
```

```
MODEL STATUS : This model conforms to the CellML 1.0 Specification released on  
10th August 2001, and the CellML Metadata 1.0 Specification released on 16th  
January, 2002.
```

```
DESCRIPTION : This file contains a CellML description of the mammalian  
ventricular action potential based on the Luo-Rudy II model, 1994. This model  
is a development of the LR-I model. In particular, the LR-II model describes  
the processes which regulate [Ca]i (intracellular Calcium concentration), and  
the movement of calcium ions through the cell and to and from the sarcoplasmic  
reticulum.
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CHANGES:
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```
18/07/2002 - CML - Added more metadata.  
09/04/2003 - AAC - Added publication date information.  
05/06/2003 - CML - Fixed MathML in a few components.  
30/07/2003 - CML - Fixed MathML in a few components.
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-->
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```
<model name="LR_II_model_1994" cmeta:id="LR_II_model_1994" xmlns="http://www.cellml.org/cellml-1.0" <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns:bqas="http://www.cellml.org/bqas/1.0" />
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```
The following RDF block contains metadata that applies to this document  
as a whole, as indicated by the empty about attribute on the  
<rdf:Description> element.
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-->
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```
<rdf:Description rdf:about="">
```

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```
The Model Builder Metadata. The Dublin Core "creator" element is used  
to indicate the person who translated the model into CellML.
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-->
```

```
<dc:creator rdf:parseType="Resource">
```

```
<vCard:N rdf:parseType="Resource">
```

```
<vCard:Family>Lloyd</vCard:Family>
```

```
<vCard:Given>Catherine</vCard:Given>
```

```
<vCard:Other>May</vCard:Other>
```

```
</vCard:N>
```

```
<vCard:EMAIL rdf:parseType="Resource">
```

```
<rdf:value>c.lloyd@auckland.ac.nz</rdf:value>
```

```
<rdf:type rdf:resource="http://imc.org/vCard/3.0#internet" />
```

```
</vCard:EMAIL>
```

```
<vCard:ORG rdf:parseType="Resource">
```

```
<vCard:Orgname>The University of Auckland</vCard:Orgname>
```

```
<vCard:Orgunit>The Bioengineering Institute</vCard:Orgunit>
```

```
</vCard:ORG>
```

```
</dc:creator>
```

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<!--
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    The Creation Date metadata. This is the date on which the model
    was translated into CellML.
-->
<dc:terms:created rdf:parseType="Resource">
  <dc:terms:W3CDTF>2002-03-28</dc:terms:W3CDTF>
</dc:terms:created>

<!--
    The Modification History metadata. This lists the changes that have been
    made to the document, who made the changes, and when they were made.
-->
<cmeta:modification rdf:parseType="Resource">
  <rdf:value>
    Fixed maths.
  </rdf:value>
  <cmeta:modifier rdf:parseType="Resource">
    <vCard:N rdf:parseType="Resource">
      <vCard:Family>Lloyd</vCard:Family>
      <vCard:Given>Catherine</vCard:Given>
      <vCard:Other>May</vCard:Other>
    </vCard:N>
  </cmeta:modifier>
  <dc:terms:modified rdf:parseType="Resource">
    <dc:terms:W3CDTF>2003-07-30</dc:terms:W3CDTF>
  </dc:terms:modified>
</cmeta:modification>
<cmeta:modification rdf:parseType="Resource">
  <rdf:value>
    Fixed maths: alpha_J_calculation in fast_sodium_current_j_gate,
    beta_K1_calculation in time_independent_potassium_current_K1_gate, and
  </rdf:value>
  <cmeta:modifier rdf:parseType="Resource">
    <vCard:N rdf:parseType="Resource">
      <vCard:Family>Lloyd</vCard:Family>
      <vCard:Given>Catherine</vCard:Given>
      <vCard:Other>May</vCard:Other>
    </vCard:N>
  </cmeta:modifier>
  <dc:terms:modified rdf:parseType="Resource">
    <dc:terms:W3CDTF>2003-06-05</dc:terms:W3CDTF>
  </dc:terms:modified>
</cmeta:modification>

<!-- The Publisher metadata. -->
<dc:publisher>
  The University of Auckland, The Bioengineering Institute
</dc:publisher>
</rdf:Description>

<!--
    The following metadata refers to the model itself, as indicated by the
    reference to the ID "LR_II_model_1994", which is declared on the
    <model> element.
-->
<rdf:Description rdf:about="#LR_II_model_1994">
  <!-- A human readable name for the model. -->
  <dc:title>
    The Luo-Rudy II Model of Mammalian Ventricular Cardiac Action
    Potentials, 1994
  </dc:title>

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i.NaK

```

</dc:title>

<!-- A comment regarding the model. -->
<cmeta:comment rdf:parseType="Resource">
  <rdf:value>
    This is the CellML description of Luo and Rudy's mathematical model of
    the mammalian cardiac ventricular action potential. It is a
    significant development on their original 1991 model.
  </rdf:value>
  <!-- The creator of the comment. -->
  <dc:creator rdf:parseType="Resource">
    <vCard:FN>Catherine Lloyd</vCard:FN>
  </dc:creator>
</cmeta:comment>

<!-- The model is relevant to all mammals. -->
<cmeta:species>Mammalia</cmeta:species>

<cmeta:bio_entity>Ventricular Myocyte</cmeta:bio_entity>

<!-- Keyword(s) -->
<bqs:reference rdf:parseType="Resource">
  <dc:subject rdf:parseType="Resource">
    <bqs:subject_type>keyword</bqs:subject_type>
    <rdf:value>
      <rdf:Bag>
        <rdf:li>Ventricular Myocyte</rdf:li>
        <rdf:li>cardiac</rdf:li>
        <rdf:li>electrophysiology</rdf:li>
      </rdf:Bag>
    </rdf:value>
  </dc:subject>
</bqs:reference>

<!--
  The CellML Metadata Specification recommends that bibliographic metadata
  is used to provide information about the original model reference. The
  "identifier" attribute on the "BibliographicReference" class provides an
  elegant way to identify a cited reference using a database identifier
  date, etc can be looked up on the database.
-->
<bqs:reference rdf:parseType="Resource">
  <bqs:Pubmed_id>7514509</bqs:Pubmed_id>
  <bqs:JournalArticle rdf:parseType="Resource">
    <dc:creator>
      <rdf:Seq>
        <rdf:li rdf:parseType="Resource">
          <bqs:Person rdf:parseType="Resource">
            <vCard:N rdf:parseType="Resource">
              <vCard:Family>Luo</vCard:Family>
              <vCard:Given>Ching-hsing</vCard:Given>
            </vCard:N>
          </bqs:Person>
        </rdf:li>
        <rdf:li rdf:parseType="Resource">
          <bqs:Person rdf:parseType="Resource">
            <vCard:N rdf:parseType="Resource">
              <vCard:Family>Rudy</vCard:Family>
              <vCard:Given>Yoram</vCard:Given>
            </vCard:N>
          </bqs:Person>
        </rdf:li>
      </rdf:Seq>
    </dc:creator>
  </bqs:JournalArticle>
</bqs:reference>

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        </vCard:N>
        </bqs:Person>
    </rdf:li>
</rdf:Seq>
</dc:creator>
<dc:title>
    A Dynamic Model of the Cardiac Ventricular Action Potential I.
</dc:title>
<dcterms:issued rdf:parseType="Resource">
    <dcterms:W3CDTF>1994-06</dcterms:W3CDTF>
</dcterms:issued>
<bqs:Journal rdf:parseType="Resource">
    <dc:title>Circulation Research</dc:title>
</bqs:Journal>
<bqs:volume>74</bqs:volume>
<bqs:first_page>1071</bqs:first_page>
<bqs:last_page>1096</bqs:last_page>
</bqs:JournalArticle>
</bqs:reference>
</rdf:Description>
</rdf:RDF>

<!--
    Below, we define some additional units for association with variables and
    constants within the model. The identifiers are fairly self-explanatory.
-->
<units name="millisecond">
    <unit prefix="milli" units="second" />
</units>

<units name="per_millisecond">
    <unit prefix="milli" units="second" exponent="-1" />
</units>

<units name="millivolt">
    <unit prefix="milli" units="volt" />
</units>

<units name="per_millivolt">
    <unit prefix="milli" units="volt" exponent="-1" />
</units>

<units name="per_millivolt_millisecond">
    <unit units="millivolt" exponent="-1" />
    <unit units="millisecond" exponent="-1" />
</units>

<units name="milliS_per_microF">
    <unit prefix="milli" units="siemens" />
    <unit prefix="milli" units="farad" exponent="-1" />
</units>

<units name="milliS_per_cm2">
    <unit prefix="milli" units="siemens" />
    <unit prefix="centi" units="metre" exponent="-2" />
</units>

<units name="nanoS_per_cm2">
    <unit prefix="nano" units="siemens" />

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```

    <unit prefix="centi" units="metre" exponent="-2" />
</units>

<units name="microF">
    <unit prefix="micro" units="farad" />
</units>

<units name="microA_per_microF">
    <unit prefix="micro" units="ampere" />
    <unit prefix="micro" units="farad" exponent="-1" />
</units>

<units name="millimolar_per_millisecond">
    <unit prefix="milli" units="mole" />
    <unit units="litre" exponent="-1" />
    <unit units="millisecond" exponent="-1" />
</units>

<units name="millimolar">
    <unit prefix="milli" units="mole" />
    <unit units="litre" exponent="-1" />
</units>

<units name="micromolar">
    <unit prefix="micro" units="mole" />
    <unit units="litre" exponent="-1" />
</units>

<units name="joule_per_kilomole_kelvin">
    <unit units="joule" />
    <unit prefix="kilo" units="mole" exponent="-1" />
    <unit units="kelvin" exponent="-1" />
</units>

<units name="coulomb_per_mole">
    <unit units="coulomb" />
    <unit units="mole" exponent="-1" />
</units>

<units name="cm_per_second">
    <unit prefix="centi" units="metre" />
    <unit units="second" exponent="-1" />
</units>

<units name="mm2">
    <unit prefix="milli" units="metre" exponent="2" />
</units>

<units name="micro_litre">
    <unit prefix="micro" units="litre" />
</units>

<!--
    The "environment" component is used to declare variables that are used by
    all or most of the other components, in this case just "time".
-->
<component name="environment">
    <variable name="time" public_interface="out" units="millisecond" />

```

```
</component>
```

```
<component name="membrane">
```

```
  <variable name="V" public_interface="out" initial_value="-84.624" units="millivolt" />  
  <variable name="R" public_interface="out" initial_value="8314.0" units="joule_per_kilomol" />  
  <variable name="T" public_interface="out" initial_value="310.0" units="kelvin" />  
  <variable name="F" public_interface="out" initial_value="96500.0" units="coulomb_per_mole" />
```

```
  <!-- These variables are defined here and only used internally. -->
```

```
  <variable name="Cm" initial_value="1.0" units="microF" />  
  <variable name="I_st" initial_value="-100.0" units="microA_per_microF" />
```

```
  <!-- These variables are imported from other components. -->
```

```
  <variable name="time" public_interface="in" units="millisecond" />  
  <variable name="i_Na" public_interface="in" units="microA_per_microF" />  
  <variable name="i_Ca_L" public_interface="in" units="microA_per_microF" />  
  <variable name="i_K" public_interface="in" units="microA_per_microF" />  
  <variable name="i_NaCa" public_interface="in" units="microA_per_microF" />  
  <variable name="i_K1" public_interface="in" units="microA_per_microF" />  
  <variable name="i_Kp" public_interface="in" units="microA_per_microF" />  
  <variable name="i_p_Ca" public_interface="in" units="microA_per_microF" />  
  <variable name="i_Na_b" public_interface="in" units="microA_per_microF" />  
  <variable name="i_Ca_b" public_interface="in" units="microA_per_microF" />  
  <variable name="i_NaK" public_interface="in" units="microA_per_microF" />  
  <variable name="i_ns_Ca" public_interface="in" units="microA_per_microF" />
```

```
  <!--
```

```
    The membrane voltage (V) is calculated as an ordinary  
    differential equation in terms of the currents.
```

```
  -->
```

```
  <math xmlns="http://www.w3.org/1998/Math/MathML">
```

```
    <apply id="membrane_voltage_diff_eq"><eq />  
      <apply><diff />  
        <bvar><ci> time </ci></bvar>  
        <ci> V </ci>  
      </apply>  
      <apply><times />  
        <apply><minus />  
          <apply><divide />  
            <cn cellml:units="dimensionless"> 1.0 </cn>  
            <ci> Cm </ci>  
          </apply>  
        </apply>  
        <apply><plus />  
          <ci> i_Na </ci>  
          <ci> i_Ca_L </ci>  
          <ci> i_K </ci>  
          <ci> i_K1 </ci>  
          <ci> i_Kp </ci>  
          <ci> i_NaCa </ci>  
          <ci> i_p_Ca </ci>  
          <ci> i_Na_b </ci>  
          <ci> i_Ca_b </ci>  
          <ci> i_NaK </ci>  
          <ci> i_ns_Ca </ci>  
          <ci> I_st </ci>  
        </apply>  
      </apply>  
    </math>
```

```

</math>
</component>

<component name="fast_sodium_current">
  <variable name="i_Na" public_interface="out" units="microA_per_microF" />
  <variable name="E_Na" public_interface="out" units="millivolt" />

  <variable name="g_Na" initial_value="16.0" units="milliS_per_microF" />

  <variable name="time" public_interface="in" private_interface="out" units="millisecond" />
  <variable name="V" public_interface="in" private_interface="out" units="millivolt" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="Nai" public_interface="in" units="millimolar" />
  <variable name="Nao" public_interface="in" units="millimolar" />

  <variable name="m" private_interface="in" units="dimensionless" />
  <variable name="h" private_interface="in" units="dimensionless" />
  <variable name="j" private_interface="in" units="dimensionless" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="i_Na_calculation"><eq />
      <ci> i_Na </ci>
      <apply><times />
        <ci> g_Na </ci>
        <apply><power />
          <ci> m </ci>
          <cn cellml:units="dimensionless"> 3.0 </cn>
        </apply>
        <ci> h </ci>
        <ci> j </ci>
        <apply><minus />
          <ci> V </ci>
          <ci> E_Na </ci>
        </apply>
      </apply>
    </math>

    <apply id="E_Na_calculation"><eq />
      <ci> E_Na </ci>
      <apply><times />
        <apply><divide />
          <apply><times />
            <ci> R </ci>
            <ci> T </ci>
          </apply>
          <ci> F </ci>
        </apply>
        <apply><ln />
          <apply><divide />
            <ci> Nao </ci>
            <ci> Nai </ci>
          </apply>
        </apply>
      </apply>
    </math>
  </component>

```

```

<component name="fast_sodium_current_m_gate">
  <variable name="m" public_interface="out" units="dimensionless" />

  <variable name="alpha_m" units="per_millisecond" />
  <variable name="beta_m" units="per_millisecond" />

  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="time" public_interface="in" units="millisecond" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="alpha_m_calculation"><eq />
    <ci> alpha_m </ci>
    <apply><divide />
      <apply><times />
        <cn cellml:units="per_millivolt_millisecond"> 0.32 </cn>
        <apply><plus />
          <ci> V </ci>
          <cn cellml:units="millivolt"> 47.13 </cn>
        </apply>
      </apply>
    </apply>
    <apply><minus />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><exp />
        <apply><times />
          <cn cellml:units="per_millivolt"> -0.1 </cn>
          <apply><plus />
            <ci> V </ci>
            <cn cellml:units="millivolt"> 47.13 </cn>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>

  <apply id="beta_m_calculation"><eq />
    <ci> beta_m </ci>
    <apply><times />
      <cn cellml:units="per_millisecond"> 0.08 </cn>
      <apply><exp />
        <apply><divide />
          <apply><minus />
            <ci> V </ci>
            </apply>
          <cn cellml:units="millivolt"> 11.0 </cn>
        </apply>
      </apply>
    </apply>

  <apply id="dm_dt"><eq />
    <apply><diff />
      <bvar><ci> time </ci></bvar>
      <ci> m </ci>
    </apply>
    <apply><minus />
      <apply><times />
        <ci> alpha_m </ci>

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        <apply><minus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> m </ci>
    </apply>
</apply>
<apply><times />
    <ci> beta_m </ci>
    <ci> m </ci>
</apply>
</apply>
</math>
</component>

<component name="fast_sodium_current_h_gate">
    <variable name="h" public_interface="out" units="dimensionless" />

    <variable name="alpha_h" units="per_millisecond" />
    <variable name="beta_h" units="per_millisecond" />

    <variable name="V" public_interface="in" units="millivolt" />
    <variable name="time" public_interface="in" units="millisecond" />

    <math xmlns="http://www.w3.org/1998/Math/MathML">
        <apply id="alpha_h_calculation"><eq />
            <ci> alpha_h </ci>
            <piecewise>
                <piece>
                    <apply><times />
                    <cn cellml:units="per_millisecond"> 0.135 </cn>
                    <apply><exp />
                    <apply><divide />
                    <apply><plus />
                    <cn cellml:units="millivolt"> 80.0 </cn>
                    <ci> V </ci>
                    </apply>
                    <cn cellml:units="millivolt"> -6.8 </cn>
                    </apply>
                </piece>
                <apply><lt />
                <ci> V </ci>
                <cn cellml:units="millivolt"> -40.0 </cn>
                </apply>
            </piecewise>
            <otherwise>
                <cn cellml:units="per_millisecond"> 0.0 </cn>
            </otherwise>
        </piecewise>
    </apply>

    <apply id="beta_h_calculation"><eq />
        <ci> beta_h </ci>
        <piecewise>
            <piece>
                <apply><plus />
                <apply><times />
                <cn cellml:units="per_millisecond"> 3.56 </cn>
            </piece>
        </piecewise>
    </apply>

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```

    <apply><exp />
      <apply><times />
        <cn cellml:units="millivolt"> 0.079 </cn>
        <ci> V </ci>
      </apply>
    </apply>
  </apply>
</apply><times />
  <cn cellml:units="per_millisecond"> 310000.0 </cn>
  <apply><exp />
    <apply><times />
      <cn cellml:units="per_millivolt"> 0.35 </cn>
      <ci> V </ci>
    </apply>
  </apply>
</apply>
</apply>
<apply><lt />
  <ci> V </ci>
  <cn cellml:units="millivolt"> -40.0 </cn>
</apply>
</piece>
<otherwise>
  <apply><divide />
    <cn cellml:units="dimensionless"> 1.0 </cn>
    <apply><times />
      <cn cellml:units="millisecond"> 0.13 </cn>
      <apply><plus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><exp />
          <apply><divide />
            <apply><plus />
              <ci> V </ci>
              <cn cellml:units="millivolt"> 10.66 </cn>
            </apply>
            <cn cellml:units="millivolt"> -11.1 </cn>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>
</otherwise>
</piecewise>
</apply>

<apply id="dh_dt"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> h </ci>
  </apply>
  <apply><minus />
    <apply><times />
      <ci> alpha_h </ci>
      <apply><minus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> h </ci>
      </apply>
    </apply>
  </apply>
</apply><times />

```

```

        <ci> beta_h </ci>
        <ci> h </ci>
    </apply>
</apply>
</math>
</component>

<component name="fast_sodium_current_j_gate">
    <variable name="j" public_interface="out" units="dimensionless" />

    <variable name="alpha_j" units="per_millisecond" />
    <variable name="beta_j" units="per_millisecond" />

    <variable name="V" public_interface="in" units="millivolt" />
    <variable name="time" public_interface="in" units="millisecond" />

    <math xmlns="http://www.w3.org/1998/Math/MathML">
        <apply id="alpha_j_calculation"><eq />
            <ci> alpha_j </ci>
            <piecewise>
                <piece>
                    <apply><times />
                    <apply><minus />
                    <apply><times />
                    <cn cellml:units="per_millivolt_millisecond"> -127140.0
</cn>

                    <apply><exp />
                    <apply><times />
                    <cn cellml:units="per_millivolt"> 0.2444 </cn>
                    <ci> V </ci>
                </apply>
            </apply>
        </apply>
        <apply><times />
        <cn cellml:units="per_millivolt_millisecond"> 0.00003474 </cn>
        <apply><exp />
        <apply><times />
        <cn cellml:units="per_millivolt"> -0.04391 </cn>
        <ci> V </ci>
    </apply>
</apply>
</math>
</component>

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```

        </apply>
    </apply>
</apply>
</apply>
</apply>
<apply><lt />
    <ci> V </ci>
    <cn cellml:units="millivolt"> -40.0 </cn>
</apply>
</piece>
<otherwise>
    <cn cellml:units="per_millisecond"> 0.0 </cn>
</otherwise>
</piecewise>
</apply>

<apply id="beta_j_calculation"><eq />
    <ci> beta_j </ci>
    <piecewise>
        <piece>
            <apply><divide />
                <apply><times />
                    <cn cellml:units="per_millisecond"> 0.1212 </cn>
                <apply><exp />
                    <apply><times />
                        <cn cellml:units="per_millivolt"> -0.01052 </cn>
                        <ci> V </ci>
                    </apply>
                </apply>
            </apply>
            <apply><plus />
                <cn cellml:units="dimensionless"> 1.0 </cn>
            <apply><exp />
                <apply><times />
                    <cn cellml:units="per_millivolt"> -0.1378 </cn>
                <apply><plus />
                    <ci> V </ci>
                    <cn cellml:units="millivolt"> 40.14 </cn>
                </apply>
            </apply>
        </piece>
        <otherwise>
            <apply><divide />
                <apply><times />
                    <cn cellml:units="per_millisecond"> 0.3 </cn>
                <apply><exp />
                    <apply><times />
                        <cn cellml:units="per_millivolt"> -0.0000002535 </cn>
                        <ci> V </ci>
                    </apply>
                </apply>
            </apply>
            <apply><plus />

```

```

    <cn cellml:units="dimensionless"> 1.0 </cn>
    <apply><exp />
      <apply><times />
        <cn cellml:units="per_millivolt"> -0.1 </cn>
        <apply><plus />
          <ci> V </ci>
          <cn cellml:units="millivolt"> 32.0 </cn>
        </apply>
      </apply>
    </apply>
  </otherwise>
</piecewise>
</apply>

<apply id="dj_dt"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> j </ci>
  </apply>
  <apply><minus />
    <apply><times />
      <ci> alpha_j </ci>
      <apply><minus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> j </ci>
      </apply>
    </apply>
    <apply><times />
      <ci> beta_j </ci>
      <ci> j </ci>
    </apply>
  </apply>
</math>
</component>

<component name="L_type_Ca_channel">
  <variable name="i_Ca_L" public_interface="out" units="microA_per_microF" />
  <variable name="i_CaCa" public_interface="out" units="microA_per_microF" />
  <variable name="i_CaK" public_interface="out" units="microA_per_microF" />
  <variable name="i_CaNa" public_interface="out" units="microA_per_microF" />
  <variable name="gamma_Nai" public_interface="out" initial_value="0.75" units="dimensionless" />
  <variable name="gamma_Nao" public_interface="out" initial_value="0.75" units="dimensionless" />
  <variable name="gamma_Ki" public_interface="out" initial_value="0.75" units="dimensionless" />
  <variable name="gamma_Ko" public_interface="out" initial_value="0.75" units="dimensionless" />

  <variable name="I_CaCa" units="microA_per_microF" />
  <variable name="I_CaK" units="microA_per_microF" />
  <variable name="I_CaNa" units="microA_per_microF" />
  <variable name="P_Ca" initial_value="0.00054" units="cm_per_second" />
  <variable name="P_Na" initial_value="0.000000675" units="cm_per_second" />
  <variable name="P_K" initial_value="0.000000193" units="cm_per_second" />
  <variable name="gamma_Cai" initial_value="1.0" units="dimensionless" />
  <variable name="gamma_Cao" initial_value="0.34" units="dimensionless" />

  <variable name="time" public_interface="in" private_interface="out" units="millisecond" />
  <variable name="V" public_interface="in" private_interface="out" units="millivolt" />

```

```

<variable name="Cai" public_interface="in" private_interface="out" units="micromolar" />
<variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
<variable name="T" public_interface="in" units="kelvin" />
<variable name="F" public_interface="in" units="coulomb_per_mole" />
<variable name="Cao" public_interface="in" units="millimolar" />
<variable name="Nao" public_interface="in" units="millimolar" />
<variable name="Ko" public_interface="in" units="millimolar" />
<variable name="Nai" public_interface="in" units="millimolar" />
<variable name="Ki" public_interface="in" units="millimolar" />

<variable name="d" private_interface="in" units="dimensionless" />
<variable name="f" private_interface="in" units="dimensionless" />
<variable name="f_Ca" private_interface="in" units="dimensionless" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="i_CaCa_calculation"><eq />
    <ci> i_CaCa </ci>
    <apply><times />
      <ci> d </ci>
      <ci> f </ci>
      <ci> f_Ca </ci>
      <ci> I_CaCa </ci>
    </apply>
  </apply>

  <apply id="i_CaNa_calculation"><eq />
    <ci> i_CaNa </ci>
    <apply><times />
      <ci> d </ci>
      <ci> f </ci>
      <ci> f_Ca </ci>
      <ci> I_CaNa </ci>
    </apply>
  </apply>

  <apply id="i_CaK_calculation"><eq />
    <ci> i_CaK </ci>
    <apply><times />
      <ci> d </ci>
      <ci> f </ci>
      <ci> f_Ca </ci>
      <ci> I_CaK </ci>
    </apply>
  </apply>

  <apply id="I_CaCa_calculation"><eq />
    <ci> I_CaCa </ci>
    <apply><times />
      <ci> P_Ca </ci>
      <apply><power />
        <cn cellml:units="dimensionless"> 2.0 </cn>
        <cn cellml:units="dimensionless"> 2.0 </cn>
      </apply>
    </apply><divide />
    <apply><times />
      <ci> V </ci>
      <apply><power />
        <ci> F </ci>
        <cn cellml:units="dimensionless"> 2.0 </cn>
      </apply>
    </apply>
  </apply>
</math>

```

```

    </apply>
  </apply>
  <apply><times />
    <ci> R </ci>
    <ci> T </ci>
  </apply>
</apply>
<apply><divide />
  <apply><minus />
    <apply><times />
      <ci> gamma_Cai </ci>
      <ci> Cai </ci>
    <apply><exp />
      <apply><divide />
        <apply><times />
          <cn cellml:units="dimensionless"> 2.0 </cn>
          <ci> V </ci>
          <ci> F </ci>
        </apply>
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><times />
    <ci> gamma_Cao </ci>
    <ci> Cao </ci>
  </apply>
</apply>
<apply><minus />
  <apply><exp />
    <apply><divide />
      <apply><times />
        <cn cellml:units="dimensionless"> 2.0 </cn>
        <ci> V </ci>
        <ci> F </ci>
      </apply>
      <apply><times />
        <ci> R </ci>
        <ci> T </ci>
      </apply>
    </apply>
  </apply>
  <cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</apply>
</apply>
<apply id="I_CaNa_calculation"><eq />
  <ci> I_CaNa </ci>
  <apply><times />
    <ci> P_Na </ci>
  <apply><power />
    <cn cellml:units="dimensionless"> 1.0 </cn>
    <cn cellml:units="dimensionless"> 2.0 </cn>
  </apply>
</apply>

```

```

<apply><divide />
  <apply><times />
    <ci> V </ci>
    <apply><power />
      <ci> F </ci>
      <cn cellml:units="dimensionless"> 2.0 </cn>
    </apply>
  </apply>
  <apply><times />
    <ci> R </ci>
    <ci> T </ci>
  </apply>
</apply>
<apply><divide />
  <apply><minus />
    <apply><times />
      <ci> gamma_Nai </ci>
      <ci> Nai </ci>
      <apply><exp />
        <apply><divide />
          <apply><times />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <ci> V </ci>
            <ci> F </ci>
          </apply>
          <apply><times />
            <ci> R </ci>
            <ci> T </ci>
          </apply>
        </apply>
      </apply>
    </apply>
    <apply><times />
      <ci> gamma_Nao </ci>
      <ci> Nao </ci>
    </apply>
  </apply>
  <apply><minus />
    <apply><exp />
      <apply><divide />
        <apply><times />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <ci> V </ci>
          <ci> F </ci>
        </apply>
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
      </apply>
    </apply>
  </apply>
  <cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</apply>
</apply>
</apply>
<apply id="I_CaK_calculation"><eq />
  <ci> I_CaK </ci>

```

```

<apply><times />
  <ci> P_K </ci>
  <apply><power />
    <cn cellml:units="dimensionless"> 1.0 </cn>
    <cn cellml:units="dimensionless"> 2.0 </cn>
  </apply>
<apply><divide />
  <apply><times />
    <ci> V </ci>
    <apply><power />
      <ci> F </ci>
      <cn cellml:units="dimensionless"> 2.0 </cn>
    </apply>
  </apply>
<apply><times />
  <ci> R </ci>
  <ci> T </ci>
</apply>
<apply><divide />
  <apply><minus />
    <apply><times />
      <ci> gamma_Ki </ci>
      <ci> Ki </ci>
    <apply><exp />
      <apply><divide />
        <apply><times />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <ci> V </ci>
          <ci> F </ci>
        </apply>
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><times />
    <ci> gamma_Ko </ci>
    <ci> Ko </ci>
  </apply>
</apply>
<apply><minus />
  <apply><exp />
    <apply><divide />
      <apply><times />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> V </ci>
        <ci> F </ci>
      </apply>
      <apply><times />
        <ci> R </ci>
        <ci> T </ci>
      </apply>
    </apply>
  </apply>
  <cn cellml:units="dimensionless"> 1.0 </cn>
</apply>

```

```

    </apply>
  </apply>
</apply>

<apply id="i_Ca_L_calculation"><eq />
  <ci> i_Ca_L </ci>
  <apply> <plus />
    <ci> i_CaCa </ci>
    <ci> i_CaK </ci>
    <ci> i_CaNa </ci>
  </apply>
</apply>
</math>
</component>

<component name="L_type_Ca_channel_d_gate">
  <variable name="d" public_interface="out" units="dimensionless" />

  <variable name="alpha_d" units="per_millisecond" />
  <variable name="beta_d" units="per_millisecond" />
  <variable name="d_infinity" units="dimensionless" />
  <variable name="tau_d" units="millisecond" />

  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="time" public_interface="in" units="millisecond" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="alpha_d_calculation"><eq />
      <ci> alpha_d </ci>
      <apply><divide />
        <ci> d_infinity </ci>
        <ci> tau_d </ci>
      </apply>
    </apply>

    <apply id="d_infinity_calculation"><eq />
      <ci> d_infinity </ci>
      <apply><divide />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><plus />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <apply><exp />
            <apply><minus />
              <apply><divide />
                <apply><plus />
                  <ci> V </ci>
                  <cn cellml:units="millivolt"> 10.0 </cn>
                </apply>
                <cn cellml:units="millivolt"> 6.24 </cn>
              </apply>
            </apply>
          </apply>
        </apply>
      </apply>
    </apply>

    <apply id="tau_d_calculation"><eq />
      <ci> tau_d </ci>
      <apply><times />

```

```

<ci> d_infinity </ci>
<apply><divide />
  <apply><minus />
    <cn cellml:units="dimensionless"> 1.0 </cn>
    <apply><exp />
      <apply><minus />
        <apply><divide />
          <apply><plus />
            <ci> V </ci>
            <cn cellml:units="millivolt"> 10.0 </cn>
          </apply>
          <cn cellml:units="millivolt"> 6.24 </cn>
        </apply>
      </apply>
    </apply>
  </apply>
  <apply><times />
    <cn cellml:units="per_millivolt_millisecond"> 0.035 </cn>
    <apply><plus />
      <ci> V </ci>
      <cn cellml:units="millivolt"> 10.0 </cn>
    </apply>
  </apply>
</apply>
</apply>
</apply>
</apply>
</math>
</component>

```

```

<component name="L_type_Ca_channel_f_gate">
  <variable name="f" public_interface="out" units="dimensionless" />

  <variable name="alpha_f" units="per_millisecond" />
  <variable name="beta_f" units="per_millisecond" />
  <variable name="f_infinity" units="dimensionless" />
  <variable name="tau_f" units="millisecond" />

  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="time" public_interface="in" units="millisecond" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="alpha_f_calculation"><eq />
      <ci> alpha_f </ci>
      <apply><divide />
        <ci> f_infinity </ci>
        <ci> tau_f </ci>
      </apply>
    </apply>

    <apply id="f_infinity_calculation"><eq />
      <ci> f_infinity </ci>
      <apply><plus />
        <apply><divide />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <apply><plus />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <apply><exp />
              <apply><divide />
                <apply><plus />
                  <ci> V </ci>
                  <cn cellml:units="millivolt"> 35.06 </cn>
                </apply>
                <cn cellml:units="millivolt"> 8.6 </cn>
              </apply>
            </apply>
          </apply>
        </apply>
      </apply>
      <cn cellml:units="dimensionless"> 0.6 </cn>
      <apply><plus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><exp />
          <apply><divide />
            <apply><minus />
              <cn cellml:units="millivolt"> 50.0 </cn>
              <ci> V </ci>
            </apply>
            <cn cellml:units="millivolt"> 20.0 </cn>
          </apply>
        </apply>
      </apply>
    </apply>

    <apply id="tau_f_calculation"><eq />
      <ci> tau_f </ci>

```

```

<apply><divide />
  <cn cellml:units="millisecond"> 1.0 </cn>
  <apply><plus />
    <apply><times />
      <cn cellml:units="dimensionless"> 0.0197 </cn>
      <apply><exp />
        <apply><minus />
          <apply><power />
            <apply><times />
              <cn cellml:units="per_millivolt"> 0.0337 </cn>
              <apply><plus />
                <ci> V </ci>
                <cn cellml:units="millivolt"> 10.0 </cn>
              </apply>
            </apply>
          </apply>
        <cn cellml:units="dimensionless"> 2.0 </cn>
      </apply>
    </apply>
  </apply>
  <cn cellml:units="dimensionless"> 0.02 </cn>
</apply>
</apply>
</apply>

<apply id="beta_f_calculation"><eq />
  <ci> beta_f </ci>
  <apply><divide />
    <apply><minus />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <ci> f_infinity </ci>
    </apply>
    <ci> tau_f </ci>
  </apply>
</apply>

<apply id="df_dt"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> f </ci>
  </apply>
  <apply><minus />
    <apply><times />
      <ci> alpha_f </ci>
      <apply><minus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> f </ci>
      </apply>
    </apply>
    <apply><times />
      <ci> beta_f </ci>
      <ci> f </ci>
    </apply>
  </apply>
</math>
</component>

<component name="L_type_Ca_channel_f_Ca_gate">

```

```

<variable name="f_Ca" public_interface="out" units="dimensionless" />

<variable name="Km_Ca" initial_value="0.6" units="micromolar" />

<variable name="V" public_interface="in" units="millivolt" />
<variable name="time" public_interface="in" units="millisecond" />
<variable name="Cai" public_interface="in" units="micromolar" />

```

```

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="f_Ca_calculation"><eq />
    <ci> f_Ca </ci>
    <apply><divide />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><plus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><power />
          <apply><divide />
            <ci> Cai </ci>
            <ci> Km_Ca </ci>
          </apply>
          <cn cellml:units="dimensionless"> 2.0 </cn>
        </apply>
      </apply>
    </apply>
  </math>
</component>

```

```

<component name="time_dependent_potassium_current">
  <variable name="i_K" public_interface="out" units="microA_per_microF" />

  <variable name="g_K" initial_value="0.282" units="milliS_per_microF" />
  <variable name="E_K" units="millivolt" />
  <variable name="PR_NaK" initial_value="0.01833" units="dimensionless" />

```

```

<variable name="time" public_interface="in" private_interface="out" units="millisecond" />
<variable name="V" public_interface="in" private_interface="out" units="millivolt" />
<variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
<variable name="T" public_interface="in" units="kelvin" />
<variable name="F" public_interface="in" units="coulomb_per_mole" />
<variable name="Ko" public_interface="in" units="millimolar" />
<variable name="Ki" public_interface="in" units="millimolar" />
<variable name="Nao" public_interface="in" units="millimolar" />
<variable name="Nai" public_interface="in" units="millimolar" />

```

```

<variable name="X" private_interface="in" units="dimensionless" />
<variable name="Xi" private_interface="in" units="dimensionless" />

```

```

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="g_K_calculation"><eq />
    <ci> g_K </ci>
    <apply><times />
      <cn cellml:units="milliS_per_cm2"> 0.282 </cn>
      <apply><root />
        <apply><divide />
          <ci> Ko </ci>
          <cn cellml:units="millimolar"> 5.4 </cn>
        </apply>
      </apply>
    </apply>
  </math>

```

```

    </apply>
  </apply>

  <apply id="E_K_calculation"><eq />
    <ci> E_K </ci>
    <apply><times />
      <apply><divide />
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
        <ci> F </ci>
      </apply>
      <apply><ln />
        <apply><divide />
          <apply><plus />
            <ci> K_o </ci>
            <apply><times />
              <ci> P_R_NaK </ci>
              <ci> N_a_o </ci>
            </apply>
          </apply>
          <apply><plus />
            <ci> K_i </ci>
            <apply><times />
              <ci> P_R_NaK </ci>
              <ci> N_a_i </ci>
            </apply>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>
</math>
</component>

<component name="time_dependent_potassium_current_X_gate">
  <variable name="X" public_interface="out" units="dimensionless" />

  <variable name="alpha_X" units="per_millisecond" />
  <variable name="beta_X" units="per_millisecond" />

  <variable name="V" public_interface="in" units="millivolt" />

```

```

<variable name="time" public_interface="in" units="millisecond" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="alpha_X_calculation"><eq />
    <ci> alpha_X </ci>
    <apply><divide />
      <apply><times />
        <cn cellml:units="per_millivolt_millisecond"> 0.0000719 </cn>
        <apply><plus />
          <ci> V </ci>
          <cn cellml:units="millivolt"> 30.0 </cn>
        </apply>
      </apply>
    <apply><minus />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><exp />
        <apply><times />
          <cn cellml:units="dimensionless"> -0.148 </cn>
          <apply><plus />
            <ci> V </ci>
            <cn cellml:units="millivolt"> 30.0 </cn>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>

  <apply id="beta_X_calculation"><eq />
    <ci> beta_X </ci>
    <apply><divide />
      <apply><times />
        <cn cellml:units="per_millivolt_millisecond"> 0.000131 </cn>
        <apply><plus />
          <ci> V </ci>
          <cn cellml:units="millivolt"> 30.0 </cn>
        </apply>
      </apply>
    <apply><plus />
      <cn cellml:units="dimensionless"> -1.0 </cn>
      <apply><exp />
        <apply><times />
          <cn cellml:units="dimensionless"> 0.0687 </cn>
          <apply><plus />
            <ci> V </ci>
            <cn cellml:units="millivolt"> 30.0 </cn>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>

  <apply id="dX_dt"><eq />
    <apply><diff />
      <bvar><ci> time </ci></bvar>
      <ci> X </ci>
    </apply>
    <apply><minus />

```

```

    <apply><times />
      <ci> alpha_X </ci>
      <apply><minus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> X </ci>
      </apply>
    </apply>
    <apply><times />
      <ci> beta_X </ci>
      <ci> X </ci>
    </apply>
  </apply>
</math>
</component>

```

```

<component name="time_dependent_potassium_current_Xi_gate">
  <variable name="Xi" public_interface="out" units="dimensionless" />

  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="time" public_interface="in" units="millisecond" />

```

```

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="Xi_calculation"><eq />
    <ci> Xi </ci>
    <apply><divide />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><plus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><exp />
          <apply><divide />
            <apply><minus />
              <ci> V </ci>
              <cn cellml:units="millivolt"> 56.26 </cn>
            </apply>
            <cn cellml:units="millivolt"> 32.1 </cn>
          </apply>
        </apply>
      </apply>
    </apply>
  </math>
</component>

```

```

<component name="time_independent_potassium_current">
  <variable name="i_K1" public_interface="out" units="microA_per_microF" />
  <variable name="E_K1" public_interface="out" private_interface="out" units="millivolt" />

  <variable name="g_K1" units="milliS_per_cm2" />

  <variable name="time" public_interface="in" private_interface="out" units="millisecond" />
  <variable name="V" public_interface="in" private_interface="out" units="millivolt" />
  <variable name="Ko" public_interface="in" units="millimolar" />
  <variable name="Ki" public_interface="in" units="millimolar" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />

  <variable name="K1_infinity" private_interface="in" units="dimensionless" />

```

```

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="g_K1_calculation"><eq />
    <ci> g_K1 </ci>
    <apply><times />
      <cn cellml:units="milliS_per_microF"> 0.75 </cn>
      <apply><root />
        <apply><divide />
          <ci> Ko </ci>
          <cn cellml:units="millimolar"> 5.4 </cn>
        </apply>
      </apply>
    </apply>
  </math>

  <apply id="E_K1_calculation"><eq />
    <ci> E_K1 </ci>
    <apply><times />
      <apply><divide />
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
        <ci> F </ci>
      </apply>
      <apply><ln />
        <apply><divide />
          <ci> Ko </ci>
          <ci> Ki </ci>
        </apply>
      </apply>
    </apply>
  </math>

  <apply id="i_K1_calculation"><eq />
    <ci> i_K1 </ci>
    <apply><times />
      <ci> g_K1 </ci>
      <ci> K1_infinity </ci>
      <apply><minus />
        <ci> V </ci>
        <ci> E_K1 </ci>
      </apply>
    </apply>
  </math>
</component>

<component name="time_independent_potassium_current_K1_gate">
  <variable name="K1_infinity" public_interface="out" units="dimensionless" />
  <variable name="alpha_K1" units="per_millisecond" />
  <variable name="beta_K1" units="per_millisecond" />

  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="E_K1" public_interface="in" units="millivolt" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="alpha_K1_calculation"><eq />

```



```

        <ci> V </ci>
        <apply><plus />
        <ci> E_K1 </ci>
        <cn cellml:units="millivolt"> 4.753 </cn>
    </apply>
</apply>
</apply>
</apply>
</apply>
</math>
</component>

<component name="plateau_potassium_current">
    <variable name="i_Kp" public_interface="out" units="microA_per_microF" />

    <variable name="E_Kp" units="millivolt" />
    <variable name="g_Kp" initial_value="0.0183" units="milliS_per_microF" />
    <variable name="Kp" units="dimensionless" />

    <variable name="time" public_interface="in" units="millisecond" />
    <variable name="V" public_interface="in" units="millivolt" />
    <variable name="E_K1" public_interface="in" units="millivolt" />

    <math xmlns="http://www.w3.org/1998/Math/MathML">
        <apply id="E_Kp_calculation"><eq />
            <ci> E_Kp </ci>
            <ci> E_K1 </ci>
        </apply>

        <apply id="Kp_calculation"><eq />
            <ci> Kp </ci>
            <apply><divide />
                <cn cellml:units="dimensionless"> 1.0 </cn>
                <apply><plus />
                    <cn cellml:units="dimensionless"> 1.0 </cn>
                    <apply><exp />
                        <apply><divide />
                            <apply><minus />
                                <cn cellml:units="millivolt"> 7.488 </cn>
                                <ci> V </ci>
                            </apply>
                        <cn cellml:units="millivolt"> 5.98 </cn>
                    </apply>
                </apply>
            </apply>
        </math>
    </component>

```

```

</apply>

<apply id="i_Kp_calculation"><eq />
  <ci> i_Kp </ci>
  <apply><times />
    <ci> g_Kp </ci>
    <ci> Kp </ci>
  <apply><minus />
    <ci> V </ci>
    <ci> E_Kp </ci>
  </apply>
</apply>
</math>
</component>

<component name="sarcolemmal_calcium_pump">
  <variable name="i_p_Ca" public_interface="out" units="microA_per_microF" />

  <variable name="K_mpCa" initial_value="0.5" units="micromolar" />
  <variable name="I_pCa" initial_value="1.15" units="microA_per_microF" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="Cai" public_interface="in" units="micromolar" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="i_p_Ca_calculation"><eq />
      <ci> i_p_Ca </ci>
      <apply><times />
        <ci> I_pCa </ci>
      <apply><divide />
        <ci> Cai </ci>
      <apply><plus />
        <ci> K_mpCa </ci>
        <ci> Cai </ci>
      </apply>
    </apply>
  </math>
</component>

<component name="sodium_background_current">
  <variable name="i_Na_b" public_interface="out" units="microA_per_microF" />

  <variable name="g_Nab" initial_value="0.00141" units="milliS_per_microF" />
  <variable name="E_NaN" units="millivolt" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="E_Na" public_interface="in" units="millivolt" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="E_NaN_calculation"><eq />
      <ci> E_NaN </ci>
      <ci> E_Na </ci>
    </apply>

    <apply id="i_Na_b_calculation"><eq />

```

```

    <ci> i_Na.b </ci>
    <apply><times />
      <ci> g_Nab </ci>
      <apply><minus />
        <ci> V </ci>
        <ci> E_NaN </ci>
      </apply>
    </apply>
  </math>
</component>

<component name="calcium_background_current">
  <variable name="i_Ca.b" public_interface="out" units="microA_per_microF" />

  <variable name="g_Cab" initial_value="0.003016" units="milliS_per_microF" />
  <variable name="E_CaN" units="millivolt" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="Cai" public_interface="in" units="micromolar" />
  <variable name="Cao" public_interface="in" units="millimolar" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="E_CaN_calculation"><eq />
    <ci> E_CaN </ci>
    <apply><times />
      <apply><divide />
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
        <apply><times />
          <cn cellml:units="dimensionless"> 2.0 </cn>
          <ci> F </ci>
        </apply>
      </apply>
    <apply><ln />
      <apply><divide />
        <ci> Cao </ci>
        <ci> Cai </ci>
      </apply>
    </apply>
  </apply>
</math>

<apply id="i_Ca.b_calculation"><eq />
  <ci> i_Ca.b </ci>
  <apply><times />
    <ci> g_Cab </ci>
    <apply><minus />
      <ci> V </ci>
      <ci> E_CaN </ci>
    </apply>
  </apply>
</math>

```

```

</math>
</component>

<component name="sodium_potassium_pump">
  <variable name="i_NaK" public_interface="out" units="microA_per_microF" />

  <variable name="I_NaK" initial_value="1.5" units="microA_per_microF" />
  <variable name="f_NaK" units="dimensionless" />
  <variable name="K_mNai" initial_value="10.0" units="millimolar" />
  <variable name="K_mKo" initial_value="1.5" units="millimolar" />
  <variable name="sigma" units="dimensionless" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="V" public_interface="in" units="millivolt" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="Nai" public_interface="in" units="millimolar" />
  <variable name="Nao" public_interface="in" units="millimolar" />
  <variable name="Ko" public_interface="in" units="millimolar" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="f_NaK_calculation"><eq />
      <ci> f_NaK </ci>
      <apply><divide />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <apply><plus />
          <apply><plus />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <apply><times />
              <cn cellml:units="dimensionless"> 0.1245 </cn>
              <apply><exp />
                <apply><times />
                  <cn cellml:units="dimensionless"> -0.1 </cn>
                  <apply><divide />
                    <apply><times />
                      <ci> V </ci>
                      <ci> F </ci>
                    </apply>
                    <apply><times />
                      <ci> R </ci>
                      <ci> T </ci>
                    </apply>
                  </apply>
                </apply>
              </apply>
            </apply>
          </apply>
        </apply>
      </apply>
      <apply><times />
        <cn cellml:units="dimensionless"> 0.0365 </cn>
        <ci> sigma </ci>
        <apply><exp />
          <apply><minus />
            <apply><divide />
              <apply><times />
                <ci> V </ci>
                <ci> F </ci>
              </apply>
            </apply>
          </apply>
        </apply>
      </apply>
    </math>
  </component>

```

```

        <ci> R </ci>
        <ci> T </ci>
    </apply>
</apply>
</apply>
</apply>
</apply>
</apply>
</apply>
</apply>
</apply>
</apply>
</apply>
</math>
</component>

<apply id="sigma_calculation"><eq />
<ci> sigma </ci>
<apply><times />
  <apply><divide />
    <cn cellml:units="dimensionless"> 1.0 </cn>
    <cn cellml:units="dimensionless"> 7.0 </cn>
  </apply>
  <apply><minus />
    <apply><exp />
      <apply><divide />
        <ci> Nao </ci>
        <cn cellml:units="dimensionless"> 67.3 </cn>
      </apply>
    </apply>
    <cn cellml:units="dimensionless"> 1.0 </cn>
  </apply>
</apply>
</math>
</component>

<apply id="i_NaK_calculation"><eq />
<ci> i_NaK </ci>
<apply><times />
  <ci> I_NaK </ci>
  <ci> f_NaK </ci>
  <apply><divide />
    <cn cellml:units="dimensionless"> 1.0 </cn>
    <apply><plus />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><power />
        <apply><divide />
          <ci> K_mNai </ci>
          <ci> Nai </ci>
        </apply>
        <cn cellml:units="dimensionless"> 1.5 </cn>
      </apply>
    </apply>
  </apply>
  <apply><divide />
    <ci> Ko </ci>
    <apply><plus />
      <ci> Ko </ci>
      <ci> K_mKo </ci>
    </apply>
  </apply>
</apply>
</math>
</component>

```

```

<component name="non_specific_calcium_activated_current">
  <variable name="i_ns_Ca" public_interface="out" units="microA_per_microF" />
  <variable name="i_ns_Na" public_interface="out" units="microA_per_microF" />
  <variable name="i_ns_K" public_interface="out" units="microA_per_microF" />

  <variable name="P_ns_Ca" initial_value="1.75E-7" units="cm_per_second" />

  <variable name="gamma_Nai" public_interface="in" units="dimensionless" />
  <variable name="gamma_Nao" public_interface="in" units="dimensionless" />
  <variable name="gamma_Ki" public_interface="in" units="dimensionless" />
  <variable name="gamma_Ko" public_interface="in" units="dimensionless" />
  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />
  <variable name="T" public_interface="in" units="kelvin" />
  <variable name="F" public_interface="in" units="coulomb_per_mole" />
  <variable name="Cao" public_interface="in" units="millimolar" />
  <variable name="Nao" public_interface="in" units="millimolar" />
  <variable name="Ko" public_interface="in" units="millimolar" />
  <variable name="Nai" public_interface="in" units="millimolar" />
  <variable name="Ki" public_interface="in" units="millimolar" />
  <variable name="I_ns_Na" units="microA_per_microF" />
  <variable name="I_ns_K" units="microA_per_microF" />
  <variable name="K_m_ns_Ca" initial_value="1.2" units="micromolar" />
  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="Cai" public_interface="in" units="micromolar" />
  <variable name="V" public_interface="in" units="millivolt" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="i_ns_Na_calculation"><eq />
      <ci> i_ns.Na </ci>
      <apply><times />
        <ci> I_ns.Na </ci>
        <apply><divide />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <apply><plus />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <apply><power />
              <apply><divide />
                <ci> K_m_ns.Ca </ci>
                <ci> Cai </ci>
              </apply>
            <cn cellml:units="dimensionless"> 3.0 </cn>
          </apply>
        </apply>
      </apply>
    </math>

    <apply id="i_ns_K_calculation"><eq />
      <ci> i_ns.K </ci>
      <apply><times />
        <ci> I_ns.K </ci>
        <apply><divide />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <apply><plus />
            <cn cellml:units="dimensionless"> 1.0 </cn>
            <apply><power />
              <apply><divide />
                <ci> K_m_ns.Ca </ci>

```



```

    <ci> Nao </ci>
  </apply>
</apply>
<apply><minus />
  <apply><exp />
    <apply><divide />
      <apply><times />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> V </ci>
        <ci> F </ci>
      </apply>
    <apply><times />
      <ci> R </ci>
      <ci> T </ci>
    </apply>
  </apply>
</apply>
<cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</apply>
</apply>

<apply id="I_ns_K_calculation"><eq />
  <ci> I_ns_K </ci>
  <apply><times />
    <ci> P_ns_Ca </ci>
    <apply><power />
      <cn cellml:units="dimensionless"> 1.0 </cn>
      <cn cellml:units="dimensionless"> 2.0 </cn>
    </apply>
  <apply><divide />
    <apply><times />
      <ci> V </ci>
      <apply><power />
        <ci> F </ci>
        <cn cellml:units="dimensionless"> 2.0 </cn>
      </apply>
    </apply>
  <apply><times />
    <ci> R </ci>
    <ci> T </ci>
  </apply>
</apply>
<apply><divide />
  <apply><minus />
    <apply><times />
      <ci> gamma_Ki </ci>
      <ci> Ki </ci>
    <apply><exp />
      <apply><divide />
        <apply><times />
          <cn cellml:units="dimensionless"> 1.0 </cn>
          <ci> V </ci>
          <ci> F </ci>
        </apply>
      <apply><times />
        <ci> R </ci>
        <ci> T </ci>
      </apply>
    </apply>
  </apply>
</apply>

```

```

        </apply>
      </apply>
    </apply>
  </apply>
  <apply><times />
    <ci> gamma_Ko </ci>
    <ci> Ko </ci>
  </apply>
</apply>
<apply><minus />
  <apply><exp />
    <apply><divide />
      <apply><times />
        <cn cellml:units="dimensionless"> 1.0 </cn>
        <ci> V </ci>
        <ci> F </ci>
      </apply>
    <apply><times />
      <ci> R </ci>
      <ci> T </ci>
    </apply>
  </apply>
</apply>
<cn cellml:units="dimensionless"> 1.0 </cn>
</apply>
</apply>
</math>
</component>

```

```

<component name="Na_Ca_exchanger">

```

```

  <variable name="i_NaCa" public_interface="out" units="microA_per_microF" />

```

```

  <variable name="K_NaCa" initial_value="2000.0" units="microA_per_microF" />

```

```

  <variable name="K_mNa" initial_value="87.5" units="millimolar" />

```

```

  <variable name="K_mCa" initial_value="1.38" units="millimolar" />

```

```

  <variable name="K_sat" initial_value="0.1" units="dimensionless" />

```

```

  <variable name="eta" initial_value="0.35" units="dimensionless" />

```

```

  <variable name="time" public_interface="in" units="millisecond" />

```

```

  <variable name="V" public_interface="in" units="millivolt" />

```

```

  <variable name="R" public_interface="in" units="joule_per_kilomole_kelvin" />

```

```

  <variable name="T" public_interface="in" units="kelvin" />

```

```

  <variable name="F" public_interface="in" units="coulomb_per_mole" />

```

```

  <variable name="Nai" public_interface="in" units="millimolar" />

```

```

  <variable name="Nao" public_interface="in" units="millimolar" />

```

```

  <variable name="Cai" public_interface="in" units="micromolar" />

```

```

  <variable name="Cao" public_interface="in" units="millimolar" />

```

```

<math xmlns="http://www.w3.org/1998/Math/MathML">

```

```

  <apply id="Na_Ca_exchanger"><eq />

```

```

    <ci> i_NaCa </ci>

```

```

    <apply><times />

```

```

      <ci> K_NaCa </ci>

```

```

    <apply><divide />

```

```

      <cn cellml:units="dimensionless"> 1.0 </cn>

```

```

    <apply><plus />

```

```

      <apply><power />

```

```

    <ci> K_mNa </ci>
    <cn cellml:units="dimensionless"> 3.0 </cn>
  </apply>
  <apply><power />
    <ci> Nao </ci>
    <cn cellml:units="dimensionless"> 3.0 </cn>
  </apply>
</apply>
<apply><divide />
  <cn cellml:units="dimensionless"> 1.0 </cn>
  <apply><plus />
    <ci> K_mCa </ci>
    <ci> Cao </ci>
  </apply>
</apply>
<apply><divide />
  <cn cellml:units="dimensionless"> 1.0 </cn>
  <apply><plus />
    <cn cellml:units="dimensionless"> 1.0 </cn>
    <apply><times />
      <ci> K_sat </ci>
      <apply><exp />
        <apply><times />
          <apply><minus />
            <ci> eta </ci>
            <cn cellml:units="dimensionless"> 1.0 </cn>
          </apply>
          <ci> V </ci>
        <apply><divide />
          <ci> F </ci>
          <apply><times />
            <ci> R </ci>
            <ci> T </ci>
          </apply>
        </apply>
      </apply>
    </apply>
  </apply>
</apply>
<apply><minus />
  <apply><times />
    <apply><exp />
      <apply><times />
        <ci> eta </ci>
        <ci> V </ci>
      <apply><divide />
        <ci> F </ci>
        <apply><times />
          <ci> R </ci>
          <ci> T </ci>
        </apply>
      </apply>
    </apply>
  </apply>
</apply>
<apply><power />
  <ci> Nai </ci>
  <cn cellml:units="dimensionless"> 3.0 </cn>

```

```

    </apply>
    <ci> Cao </ci>
  </apply>
</apply><times />
  <apply><exp />
    <apply><times />
      <apply><minus />
        <ci> eta </ci>
        <cn cellml:units="dimensionless"> 1.0 </cn>
      </apply>
      <ci> V </ci>
    </apply><divide />
      <ci> F </ci>
    </apply><times />
      <ci> R </ci>
      <ci> T </ci>
    </apply>
  </apply>
</apply>
<apply><power />
  <ci> Nao </ci>
  <cn cellml:units="dimensionless"> 3.0 </cn>
</apply>
<ci> Cai </ci>
</apply>
</apply>
</math>
</component>

```

```

<component name="calcium_buffers_in_the_myoplasm">
  <variable name="K_mTn" initial_value="0.5" units="micromolar" />
  <variable name="K_mCMDN" initial_value="2.38" units="micromolar" />
  <variable name="Tn_max" initial_value="70.0" units="micromolar" />
  <variable name="CMDN_max" initial_value="50.0" units="micromolar" />

```

```

  <variable name="Tn_buff" units="micromolar" />
  <variable name="CMDN_buff" units="micromolar" />

```

```

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="Cai" public_interface="in" units="micromolar" />

```

```

<math xmlns="http://www.w3.org/1998/Math/MathML">

```

```

  <apply id="Tn_buff_calculation"><eq />

```

```

    <ci> Tn_buff </ci>

```

```

    <apply><times />

```

```

      <ci> Tn_max </ci>

```

```

      <apply><divide />

```

```

        <ci> Cai </ci>

```

```

        <apply><plus />

```

```

          <ci> Cai </ci>

```

```

          <ci> K_mTn </ci>

```

```

        </apply>

```

```

      </apply>

```

```

    </apply>

```

```

  </math>

```

```

<apply id="CMDN_buff_calculation"><eq />
  <ci> CMDN_buff </ci>
  <apply><times />
    <ci> CMDN_max </ci>
    <apply><divide />
      <ci> Cai </ci>
      <apply><plus />
        <ci> Cai </ci>
        <ci> K_mCMDN </ci>
      </apply>
    </apply>
  </apply>
</math>
</component>

<component name="calcium_fluxes_in_the_SR">
  <variable name="i_rel" public_interface="out" units="millimolar_per_millisecond" />
  <variable name="i_up" public_interface="out" units="millimolar_per_millisecond" />
  <variable name="i_leak" public_interface="out" units="millimolar_per_millisecond" />
  <variable name="i_tr" public_interface="out" units="millimolar_per_millisecond" />

  <variable name="G_rel" units="per_millisecond" />
  <variable name="G_rel_max" units="per_millisecond" />
  <variable name="tau_on" initial_value="2.0" units="millisecond" />
  <variable name="tau_off" initial_value="2.0" units="millisecond" />
  <variable name="tau_tr" initial_value="180.0" units="millisecond" />
  <variable name="t" initial_value="0.0" units="millisecond" />
  <variable name="K_mrel" initial_value="0.8" units="micromolar" />
  <variable name="delta_Ca_i2" units="micromolar" />
  <variable name="delta_Ca_ith" initial_value="0.18" units="micromolar" />
  <variable name="CSQN_buff" units="millimolar" />
  <variable name="CSQN_max" initial_value="10.0" units="millimolar" />
  <variable name="CSQN_th" initial_value="0.7" units="millimolar" />
  <variable name="K_mCSQN" initial_value="0.8" units="millimolar" />
  <variable name="K_mup" initial_value="0.92" units="micromolar" />
  <variable name="K_leak" units="per_millisecond" />
  <variable name="I_up" initial_value="0.005" units="millimolar_per_millisecond" />
  <variable name="Ca_NSR_max" initial_value="0.15" units="millimolar" />
  <variable name="calcium_overload" units="dimensionless" />

  <variable name="time" public_interface="in" units="millisecond" />
  <variable name="Cai" public_interface="in" units="micromolar" />
  <variable name="Ca_JSR" public_interface="in" units="millimolar" />
  <variable name="Ca_NSR" public_interface="in" units="millimolar" />

  <math xmlns="http://www.w3.org/1998/Math/MathML">
    <apply id="i_rel_calculation"><eq />
      <ci> i_rel </ci>
      <apply><times />
        <ci> G_rel </ci>
        <apply><minus />
          <ci> Ca_JSR </ci>
          <ci> Cai </ci>
        </apply>
      </apply>
    </math>

    <apply id="G_rel_calculation"><eq />

```

```

<ci> G_rel </ci>
<piecewise>
  <piece>
    <apply><times />
      <ci> G_rel_max </ci>
      <apply><divide />
        <apply><minus />
          <ci> delta_Ca_i2 </ci>
          <ci> delta_Ca_ith </ci>
        </apply>
        <apply><minus />
          <apply><plus />
            <ci> K_mrel </ci>
            <ci> delta_Ca_i2 </ci>
          </apply>
          <ci> delta_Ca_ith </ci>
        </apply>
      </apply>
    <apply><minus />
      <cn cellml:units="dimensionless"> 1.0 </cn>
    <apply><exp />
      <apply><minus />
        <apply><divide />
          <ci> t </ci>
          <ci> tau_on </ci>
        </apply>
      </apply>
    <apply><exp />
      <apply><minus />
        <apply><divide />
          <ci> t </ci>
          <ci> tau_off </ci>
        </apply>
      </apply>
    <apply><eq />
      <ci> calcium_overload </ci>
      <cn cellml:units="dimensionless"> 0.0 </cn>
    </apply>
  </piece>
  <otherwise>
    <apply><times />
      <ci> G_rel_max </ci>
      <apply><minus />
        <cn cellml:units="dimensionless"> 1.0 </cn>
      <apply><exp />
        <apply><minus />
          <apply><divide />
            <ci> t </ci>
            <ci> tau_on </ci>
          </apply>
        </apply>
      </apply>
    <apply><exp />
      <apply><minus />

```

```

        <apply><divide />
        <ci> t </ci>
        <ci> tau.off </ci>
    </apply>
</apply>
</apply>
</apply>
</otherwise>
</piecewise>
</apply>

<apply id="G_rel_max_calculation"><eq />
<ci> G_rel_max </ci>
<piecewise>
    <piece>
        <piecewise>
            <piece>
                <cn cellml:units="per_millisecond"> 0.0 </cn>
                <apply><lt />
                <ci> delta.Ca.i2 </ci>
                <ci> delta.Ca.ith </ci>
            </apply>
        </piece>
        <otherwise>
            <cn cellml:units="per_millisecond"> 60.0 </cn>
        </otherwise>
    </piecewise>
    <apply><eq />
    <ci> calcium_overload </ci>
    <cn cellml:units="dimensionless"> 0.0 </cn>
</apply>
</piece>
<otherwise>
    <piecewise>
        <piece>
            <cn cellml:units="per_millisecond"> 0.0 </cn>
            <apply><lt />
            <ci> CSQN_buff </ci>
            <ci> CSQN.th </ci>
        </apply>
        </piece>
        <otherwise>
            <cn cellml:units="per_millisecond"> 4.0 </cn>
        </otherwise>
    </piecewise>
</otherwise>
</piecewise>
</apply>

<apply id="CSQN_buff_calculation"><eq />
<ci> CSQN_buff </ci>
<apply><times />
    <ci> CSQN_max </ci>
    <apply><divide />
        <ci> Ca_JSR </ci>
        <apply><plus />
            <ci> Ca_JSR </ci>
            <ci> K_mCSQN </ci>
    </apply>
</apply>

```

```

    </apply>
  </apply>
</apply>

<apply id="i_up_calculation"><eq />
  <ci> i_up </ci>
  <apply><times />
    <ci> I_up </ci>
    <apply><divide />
      <ci> Cai </ci>
      <apply><plus />
        <ci> Cai </ci>
        <ci> K_mup </ci>
      </apply>
    </apply>
  </apply>
</apply>

<apply id="i_leak_calcualtion"><eq />
  <ci> i_leak </ci>
  <apply><times />
    <ci> K_leak </ci>
    <ci> Ca_NSR </ci>
  </apply>
</apply>

<apply id="K_leak_calculation"><eq />
  <ci> K_leak </ci>
  <apply><divide />
    <ci> I_up </ci>
    <ci> Ca_NSR_max </ci>
  </apply>
</apply>

<apply id="i_tr_calculation"><eq />
  <ci> i_tr </ci>
  <apply><divide />
    <apply><minus />
      <ci> Ca_NSR </ci>
      <ci> Ca_JSR </ci>
    </apply>
    <ci> tau_tr </ci>
  </apply>
</apply>
</math>
</component>

<component name="ionic_concentrations">
  <variable name="Nai" public_interface="out" initial_value="10.0" units="millimolar" />
  <variable name="Nao" public_interface="out" initial_value="140.0" units="millimolar" />
  <variable name="Cai" public_interface="out" initial_value="0.12" units="micromolar" />
  <variable name="Cao" public_interface="out" initial_value="1.8" units="millimolar" />
  <variable name="Ki" public_interface="out" initial_value="145.0" units="millimolar" />
  <variable name="Ko" public_interface="out" initial_value="5.4" units="millimolar" />
  <variable name="Ca_JSR" public_interface="out" units="millimolar" />
  <variable name="Ca_NSR" public_interface="out" initial_value="15.0" units="millimolar" />
  <variable name="Ca_foot" units="micromolar" />

  <variable name="A_cap" initial_value="0.000153" units="mm2" />

```

```

<variable name="R_A_V" units="dimensionless" />
<variable name="V_myo" units="micro_litre" />
<variable name="V_cleft" units="micro_litre" />
<variable name="V_JSR" units="micro_litre" />
<variable name="V_NSR" units="micro_litre" />

<variable name="time" public_interface="in" units="millisecond" />
<variable name="F" public_interface="in" units="coulomb_per_mole" />
<variable name="i_Na" public_interface="in" units="microA_per_microF" /> <variabl
<variable name="i_Na_b" public_interface="in" units="microA_per_microF" />
<variable name="i_ns_Na" public_interface="in" units="microA_per_microF" /> <variabl
<variable name="i_NaK" public_interface="in" units="microA_per_microF" />
<variable name="i_CaCa" public_interface="in" units="microA_per_microF" />
<variable name="i_CaK" public_interface="in" units="microA_per_microF" />
<variable name="i_p_Ca" public_interface="in" units="microA_per_microF" />
<variable name="i_Ca_b" public_interface="in" units="microA_per_microF" />
<variable name="i_K" public_interface="in" units="microA_per_microF" />
<variable name="i_K1" public_interface="in" units="microA_per_microF" />
<variable name="i_Kp" public_interface="in" units="microA_per_microF" /> <variabl
<variable name="i_tr" public_interface="in" units="millimolar_per_millisecond" />
<variable name="i_rel" public_interface="in" units="millimolar_per_millisecond" />
<variable name="i_leak" public_interface="in" units="millimolar_per_millisecond" />
<variable name="i_up" public_interface="in" units="millimolar_per_millisecond" />

<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply id="sodium_diff_eq"><eq />
    <apply><diff />
      <bvar><ci> time </ci></bvar>
      <ci> Nai </ci>
    </apply>
    <apply><times />
      <apply><minus />
        <apply><plus />
          <ci> i_Na </ci>
          <ci> i_CaNa </ci>
          <ci> i_Na_b </ci>
          <ci> i_ns_Na </ci>
        </apply><times />
        <ci> i_NaCa </ci>
        <cn cellml:units="dimensionless"> 3.0 </cn>
      </apply>
      <apply><times />
        <ci> i_NaK </ci>
        <cn cellml:units="dimensionless"> 3.0 </cn>
      </apply>
    </apply>
  </apply>
  <apply><divide />
    <ci> A_cap </ci>
    <apply><times />
      <ci> V_myo </ci>
      <ci> F </ci>
    </apply>
  </apply>
</math>

<apply id="calcium_internal_diff_eq"><eq />
  <apply><diff />

```

```

    <bvar><ci> time </ci></bvar>
    <ci> Cai </ci>
</apply>
<apply><plus />
  <apply><times />
    <apply><minus />
      <apply><plus />
        <ci> i_CaCa </ci>
        <ci> i_p_Ca </ci>
        <ci> i_Ca_b </ci>
      </apply>
      <ci> i_NaCa </ci>
    </apply>
    <apply><divide />
      <ci> A_cap </ci>
      <apply><times />
        <cn cellml:units="dimensionless"> 2.0 </cn>
        <ci> V_myo </ci>
        <ci> F </ci>
      </apply>
    </apply>
  </apply>
<apply><times />
  <ci> i_rel </ci>
  <apply><divide />
    <ci> V_JSR </ci>
    <ci> V_myo </ci>
  </apply>
</apply>
<apply><times />
  <apply><minus />
    <ci> i_leak </ci>
    <ci> i_up </ci>
  </apply>
  <apply><divide />
    <ci> V_NSR </ci>
    <ci> V_myo </ci>
  </apply>
</apply>
</apply>
</apply>
</apply>
</apply>
<apply id="potassium_internal_diff_eq"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> Ki </ci>
  </apply>
  <apply><times />
    <apply><minus />
      <apply><plus />
        <ci> i_CaK </ci>
        <ci> i_K </ci>
        <ci> i_K1 </ci>
        <ci> i_Kp </ci>
        <ci> i_ns_K </ci>
      </apply>
      <apply><minus />
        <apply><times />
          <ci> i_NaK </ci>
          <cn cellml:units="dimensionless"> 2.0 </cn>
        </apply>
      </apply>
    </apply>
  </apply>
</apply>

```

```

        </apply>
    </apply>
</apply>
</apply>
<apply><divide />
    <ci> A_cap </ci>
    <apply><times />
        <ci> V_myo </ci>
        <ci> F </ci>
    </apply>
</apply>
</apply>
</apply>
</apply>

<apply id="potassium_external_diff_eq"><eq />
    <apply><diff />
        <bvar><ci> time </ci></bvar>
        <ci> Ko </ci>
    </apply>
    <apply><times />
        <apply><plus />
            <ci> i_CaK </ci>
            <ci> i_K </ci>
            <ci> i_Kl </ci>
            <ci> i_Kp </ci>
            <ci> i_ns_K </ci>
        </apply><minus />
        <apply><times />
            <ci> i_NaK </ci>
            <cn cellml:units="dimensionless"> 2.0 </cn>
        </apply>
    </apply>
    <apply><divide />
        <ci> A_cap </ci>
        <apply><times />
            <ci> V_cleft </ci>
            <ci> F </ci>
        </apply>
    </apply>
</apply>
</apply>

<apply id="calcium_JSR_diff_eq"><eq />
    <apply><diff />
        <bvar><ci> time </ci></bvar>
        <ci> Ca_JSR </ci>
    </apply>
    <apply><minus />
        <apply><minus />
            <ci> i_rel </ci>
            <apply><times />
                <ci> i_tr </ci>
                <apply><divide />
                    <ci> V_NSR </ci>
                    <ci> V_JSR </ci>
                </apply>
            </apply>
        </apply>
    </apply>
</apply>

```

```

    </apply>
</apply>

<apply id="calcium_NSR_diff_eq"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> Ca_NSR </ci>
  </apply>
  <apply><minus />
    <apply><minus />
      <apply><plus />
        <ci> i_leak </ci>
        <ci> i_tr </ci>
      </apply>
      <ci> i_up </ci>
    </apply>
  </apply>
</apply>

<apply id="calcium_foot_diff_eq"><eq />
  <apply><diff />
    <bvar><ci> time </ci></bvar>
    <ci> Ca_foot </ci>
  </apply>
  <apply><times />
    <apply><minus />
      <ci> i_CaCa </ci>
    </apply>
    <apply><divide />
      <ci> A_cap </ci>
      <apply><times />
        <cn cellml:units="dimensionless"> 2.0 </cn>
        <ci> V_myo </ci>
        <ci> F </ci>
      </apply>
    </apply>
    <ci> R_A_V </ci>
  </apply>
</math>
</component>

<group>
  <relationship_ref relationship="containment" />
  <component_ref component="membrane">
    <component_ref component="fast_sodium_current">
      <component_ref component="fast_sodium_current_m_gate" />
      <component_ref component="fast_sodium_current_h_gate" />
      <component_ref component="fast_sodium_current_j_gate" />
    </component_ref>
    <component_ref component="L_type_Ca_channel">
      <component_ref component="L_type_Ca_channel_d_gate" />
      <component_ref component="L_type_Ca_channel_f_gate" />
      <component_ref component="L_type_Ca_channel_f_Ca_gate" />
    </component_ref>
    <component_ref component="time_dependent_potassium_current">
      <component_ref component="time_dependent_potassium_current_X_gate" />
      <component_ref component="time_dependent_potassium_current_Xi_gate" />
    </component_ref>
  </group>

```

```

    <component_ref component="time_independent_potassium_current">
      <component_ref component="time_independent_potassium_current_K1_gate" />
    </component_ref>
    <component_ref component="Na_Ca_exchanger" />
    <component_ref component="plateau_potassium_current" />
    <component_ref component="sarcolemmal_calcium_pump" />
    <component_ref component="sodium_background_current" />
    <component_ref component="calcium_background_current" />
    <component_ref component="sodium_potassium_pump" />
    <component_ref component="non_specific_calcium_activated_current" />
    <component_ref component="ionic_concentrations" />
    <component_ref component="calcium_buffers_in_the_myoplasm" />
    <component_ref component="calcium_fluxes_in_the_SR" />
  </component_ref>
</group>

```

```

<group>
  <relationship_ref relationship="encapsulation" />
  <component_ref component="fast_sodium_current">
    <component_ref component="fast_sodium_current_m_gate" />
    <component_ref component="fast_sodium_current_h_gate" />
    <component_ref component="fast_sodium_current_j_gate" />
  </component_ref>
  <component_ref component="L_type_Ca_channel">
    <component_ref component="L_type_Ca_channel_d_gate" />
    <component_ref component="L_type_Ca_channel_f_gate" />
    <component_ref component="L_type_Ca_channel_f_Ca_gate" />
  </component_ref>
  <component_ref component="time_dependent_potassium_current">
    <component_ref component="time_dependent_potassium_current_X_gate" />
    <component_ref component="time_dependent_potassium_current_Xi_gate" />
  </component_ref>
  <component_ref component="time_independent_potassium_current">
    <component_ref component="time_independent_potassium_current_K1_gate" />
  </component_ref>
</group>

```

```

<connection>
  <map_components component_1="membrane" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

```

```

<connection>
  <map_components component_1="fast_sodium_current" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

```

```

<connection>
  <map_components component_1="L_type_Ca_channel" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />
</connection>

```

```

<connection>
  <map_components component_1="time_dependent_potassium_current" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />

```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="time_independent_potassium_current" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="Na_Ca_exchanger" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="plateau_potassium_current" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="sarcolemmal_calcium_pump" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="sodium_background_current" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="calcium_background_current" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="sodium_potassium_pump" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="non_specific_calcium_activated_current" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="ionic_concentrations" component_2="environment" />
```

```
  <map_variables variable_1="time" variable_2="time" />
```

```
</connection>
```

```
<connection>
```

```
  <map_components component_1="calcium_buffers_in_the_myoplasm" component_2="environment" />
```

```
<map_variables variable_1="time" variable_2="time" />
</connection>
```

```
<connection>
  <map_components component_1="calcium_fluxes_in_the_SR" component_2="environment" />
  <map_variables variable_1="time" variable_2="time" />
</connection>
```

```
<connection>
  <map_components component_1="membrane" component_2="fast_sodium_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_Na" variable_2="i_Na" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
</connection>
```

```
<connection>
  <map_components component_1="membrane" component_2="L_type_Ca_channel" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_Ca_L" variable_2="i_Ca_L" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
</connection>
```

```
<connection>
  <map_components component_1="membrane" component_2="time_dependent_potassium_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_K" variable_2="i_K" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
</connection>
```

```
<connection>
  <map_components component_1="membrane" component_2="Na_Ca_exchanger" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_NaCa" variable_2="i_NaCa" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
</connection>
```

```
<connection>
  <map_components component_1="membrane" component_2="time_independent_potassium_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_K1" variable_2="i_K1" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
</connection>
```

```

<connection>
  <map_components component_1="membrane" component_2="plateau_potassium_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_Kp" variable_2="i_Kp" />
</connection>

<connection>
  <map_components component_1="membrane" component_2="sarcolemmal_calcium_pump" />
  <map_variables variable_1="i_p_Ca" variable_2="i_p_Ca" />
</connection>

<connection>
  <map_components component_1="membrane" component_2="sodium_background_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_Na_b" variable_2="i_Na_b" />
</connection>

<connection>
  <map_components component_1="membrane" component_2="calcium_background_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_Ca_b" variable_2="i_Ca_b" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
</connection>

<connection>
  <map_components component_1="membrane" component_2="sodium_potassium_pump" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="i_NaK" variable_2="i_NaK" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
</connection>

<connection>
  <map_components component_1="membrane" component_2="non_specific_calcium_activated_current" />
  <map_variables variable_1="V" variable_2="V" />
  <map_variables variable_1="R" variable_2="R" />
  <map_variables variable_1="T" variable_2="T" />
  <map_variables variable_1="F" variable_2="F" />
  <map_variables variable_1="i_ns_Ca" variable_2="i_ns_Ca" />
</connection>

<connection>
  <map_components component_1="membrane" component_2="ionic_concentrations" />
  <map_variables variable_1="F" variable_2="F" />
</connection>

<connection>
  <map_components component_1="fast_sodium_current" component_2="ionic_concentrations" />
  <map_variables variable_1="i_Na" variable_2="i_Na" />
  <map_variables variable_1="Nao" variable_2="Nao" />

```

```
<map_variables variable_1="Nai" variable_2="Nai" />
</connection>
```

```
<connection>
  <map_components component_1="fast_sodium_current" component_2="sodium_background_current" />
  <map_variables variable_1="E_Na" variable_2="E_Na" />
</connection>
```

```
<connection>
  <map_components component_1="L_type_Ca_channel" component_2="ionic_concentrations" />
  <map_variables variable_1="Cai" variable_2="Cai" />
  <map_variables variable_1="Cao" variable_2="Cao" />
  <map_variables variable_1="Nao" variable_2="Nao" />
  <map_variables variable_1="Nai" variable_2="Nai" />
  <map_variables variable_1="Ko" variable_2="Ko" />
  <map_variables variable_1="Ki" variable_2="Ki" />
  <map_variables variable_1="i_CaCa" variable_2="i_CaCa" />
  <map_variables variable_1="i_CaNa" variable_2="i_CaNa" />
  <map_variables variable_1="i_CaK" variable_2="i_CaK" />
</connection>
```

```
<connection>
  <map_components component_1="time_dependent_potassium_current" component_2="ionic_concentrations" />
  <map_variables variable_1="Ki" variable_2="Ki" />
  <map_variables variable_1="Ko" variable_2="Ko" />
  <map_variables variable_1="Nao" variable_2="Nao" />
  <map_variables variable_1="Nai" variable_2="Nai" />
  <map_variables variable_1="i_K" variable_2="i_K" />
</connection>
```

```
<connection>
  <map_components component_1="Na_Ca_exchanger" component_2="ionic_concentrations" />
  <map_variables variable_1="Cai" variable_2="Cai" />
  <map_variables variable_1="Nai" variable_2="Nai" />
  <map_variables variable_1="Cao" variable_2="Cao" />
  <map_variables variable_1="Nao" variable_2="Nao" />
  <map_variables variable_1="i_NaCa" variable_2="i_NaCa" />
</connection>
```

```
<connection>
  <map_components component_1="time_independent_potassium_current" component_2="ionic_concentrations" />
  <map_variables variable_1="Ki" variable_2="Ki" />
  <map_variables variable_1="Ko" variable_2="Ko" />
  <map_variables variable_1="i_K1" variable_2="i_K1" />
</connection>
```

```
<connection>
  <map_components component_1="plateau_potassium_current" component_2="time_independent_potassium_current" />
  <map_variables variable_1="E_K1" variable_2="E_K1" />
</connection>
```

```
<connection>
```

```

    <map_components component_1="plateau_potassium_current" component_2="ionic_concentrations"
    <map_variables variable_1="i_Kp" variable_2="i_Kp" />
</connection>

<connection>
    <map_components component_1="sarcolemmal_calcium_pump" component_2="ionic_concentrations"
    <map_variables variable_1="i_p_Ca" variable_2="i_p_Ca" />
    <map_variables variable_1="Cai" variable_2="Cai" />
</connection>

<connection>
    <map_components component_1="sodium_background_current" component_2="ionic_concentrations"
    <map_variables variable_1="i_Na_b" variable_2="i_Na_b" />
</connection>

<connection>
    <map_components component_1="calcium_background_current" component_2="ionic_concentrations"
    <map_variables variable_1="Cai" variable_2="Cai" />
    <map_variables variable_1="Cao" variable_2="Cao" />
    <map_variables variable_1="i_Ca_b" variable_2="i_Ca_b" />
</connection>

<connection>
    <map_components component_1="sodium_potassium_pump" component_2="ionic_concentrations" />
    <map_variables variable_1="Nai" variable_2="Nai" />
    <map_variables variable_1="Nao" variable_2="Nao" />
    <map_variables variable_1="Ko" variable_2="Ko" />
    <map_variables variable_1="i_NaK" variable_2="i_NaK" />
</connection>

<connection>
    <map_components component_1="non_specific_calcium_activated_current" component_2="ionic_concentrations"
    <map_variables variable_1="Cai" variable_2="Cai" />
    <map_variables variable_1="Cao" variable_2="Cao" />
    <map_variables variable_1="Nao" variable_2="Nao" />
    <map_variables variable_1="Nai" variable_2="Nai" />
    <map_variables variable_1="Ko" variable_2="Ko" />
    <map_variables variable_1="Ki" variable_2="Ki" />
    <map_variables variable_1="i_ns_Na" variable_2="i_ns_Na" />
    <map_variables variable_1="i_ns_K" variable_2="i_ns_K" />
</connection>

<connection>
    <map_components component_1="calcium_buffers_in_the_myoplasm" component_2="ionic_concentrations"
    <map_variables variable_1="Cai" variable_2="Cai" />
</connection>

<connection>
    <map_components component_1="calcium_fluxes_in_the_SR" component_2="ionic_concentrations"
    <map_variables variable_1="i_rel" variable_2="i_rel" />
    <map_variables variable_1="i_tr" variable_2="i_tr" />
    <map_variables variable_1="i_leak" variable_2="i_leak" />

```

```

    <map_variables variable_1="i_up" variable_2="i_up" />
    <map_variables variable_1="Cai" variable_2="Cai" />
    <map_variables variable_1="Ca_JSR" variable_2="Ca_JSR" />
    <map_variables variable_1="Ca_NSR" variable_2="Ca_NSR" />
</connection>

<connection>
    <map_components component_1="L_type_Ca_channel" component_2="non_specific_calcium_activa
    <map_variables variable_1="gamma_Nao" variable_2="gamma_Nao" />
    <map_variables variable_1="gamma_Nai" variable_2="gamma_Nai" />
    <map_variables variable_1="gamma_Ko" variable_2="gamma_Ko" />
    <map_variables variable_1="gamma_Ki" variable_2="gamma_Ki" />
</connection>

<connection>
    <map_components component_1="fast_sodium_current" component_2="fast_sodium_current_m_gat
    <map_variables variable_1="m" variable_2="m" />
    <map_variables variable_1="time" variable_2="time" />
    <map_variables variable_1="V" variable_2="V" />
</connection>

<connection>
    <map_components component_1="fast_sodium_current" component_2="fast_sodium_current_h_gat
    <map_variables variable_1="h" variable_2="h" />
    <map_variables variable_1="time" variable_2="time" />
    <map_variables variable_1="V" variable_2="V" />
</connection>

<connection>
    <map_components component_1="fast_sodium_current" component_2="fast_sodium_current_j_gat
    <map_variables variable_1="j" variable_2="j" />
    <map_variables variable_1="time" variable_2="time" />
    <map_variables variable_1="V" variable_2="V" />
</connection>

<connection>
    <map_components component_1="L_type_Ca_channel" component_2="L_type_Ca_channel_d_gate" />
    <map_variables variable_1="d" variable_2="d" />
    <map_variables variable_1="time" variable_2="time" />
    <map_variables variable_1="V" variable_2="V" />
</connection>

<connection>
    <map_components component_1="L_type_Ca_channel" component_2="L_type_Ca_channel_f_gate" />
    <map_variables variable_1="f" variable_2="f" />
    <map_variables variable_1="time" variable_2="time" />
    <map_variables variable_1="V" variable_2="V" />
</connection>

<connection>
    <map_components component_1="L_type_Ca_channel" component_2="L_type_Ca_channel_f_Ca_gate
    <map_variables variable_1="f_Ca" variable_2="f_Ca" />
    <map_variables variable_1="time" variable_2="time" />
    <map_variables variable_1="Cai" variable_2="Cai" />

```

```
<map_variables variable_1="V" variable_2="V" />
</connection>
```

```
<connection>
  <map_components component_1="time_dependent_potassium_current" component_2="time_dependent_potassium_current" />
  <map_variables variable_1="X" variable_2="X" />
  <map_variables variable_1="time" variable_2="time" />
  <map_variables variable_1="V" variable_2="V" />
</connection>
```

```
<connection>
  <map_components component_1="time_dependent_potassium_current" component_2="time_dependent_potassium_current" />
  <map_variables variable_1="Xi" variable_2="Xi" />
  <map_variables variable_1="time" variable_2="time" />
  <map_variables variable_1="V" variable_2="V" />
</connection>
```

```
<connection>
  <map_components component_1="time_independent_potassium_current" component_2="time_independent_potassium_current" />
  <map_variables variable_1="K1_infinity" variable_2="K1_infinity" />
  <map_variables variable_1="E_K1" variable_2="E_K1" />
  <map_variables variable_1="time" variable_2="time" />
  <map_variables variable_1="V" variable_2="V" />
</connection>
```

```
</model>
```